PROMOTING MOTOR DEVELOPMENT IN CHILDREN IN THE COVID-19 ERA: SCIENCE AND APPLICATIONS

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Editorial: Promoting motor development in children in the COVID-19 era: Science and applications

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KEYWORDS

motor development, pandemic (COVID-19), physical activity, children, education

Editorial on the Research Topic
Promoting motor development in children in the COVID-19 era: Science and applications

At the dawn of 2020, the World Health Organization (WHO) announced the presence of a novel strain of coronavirus; by March, WHO declared that COVID-19 met the criteria of a pandemic (globally widespread and sustained disease transmission among humans). The implications of a global pandemic were immediate and profound. For many children, the COVID-19 pandemic meant that they were confined indoors for an indefinite amount of time. They could no longer go to school in-person, play on their local sports teams, or congregate in parks and on playgrounds. The consequences of the COVID-19 pandemic on motor development have the potential to be profound on infants and children of all ages, and to have a lasting impact on many distinct aspects of development for years to come. It is for that reason that we felt it imperative to share research related to the direct and indirect impacts of COVID-19 on motor development. We chose to explore this topic as broadly as possible. The nine publications included in this Research Topic represent a wide range of subjects, participant ages, as well as represented countries, making it a truly global examination of the impact of COVID-19 on the development of motor skills.

Two studies focus on the differences that emerged during the COVID-19 pandemic in the development of infants (Huang et al.) and young children (Auilar-Farias et al.). In Huang et al., the authors explore associations among motor and communication characteristics in born prior to and during the COVID-19 pandemic, arguing that the social isolation experienced by the latter group may lead to motor and communication delays. In fact, they determined that infants who experienced social isolation during the pandemic had an increased risk of compromised neurodevelopment, but only if the infant was first born. This suggests that siblings played a vital role in maintaining infant

motor development, which in turn underscores the importance of interactions with other children to avoid motor delays. The next study by Aguilar-Faris and colleagues, also explores the behavioral and emotional changes that resulted from the pandemic in toddlers and young children in Chile. They surveyed almost 2,000 caregivers about changes in their children's emotional and motor behaviors along with their own levels of stress. They found that children significantly reduced their physical activity while concomitantly increasing screen time; further, children's sleep quality declined in the early pandemic. Further (and not surprisingly), caregivers increased their levels of irritability, tiredness and stress, and this was associated with negative changes in children's emotions and behaviors.

In a related study that has implications for social isolation experienced by children during COVID-19, Gil-Mardrona et al. examined the impact of the presence or absence of siblings as well as participation in extracurricular activities on motor development. The authors used the checklist of Psychomotor Activities (CPA) to assess multiple aspects of motor behavior such as postural control, balance, and coordination in almost 700 Spanish children aged 5 years old. They determined that participation in extracurricular activities—experiences that essentially disappeared during the pandemic—provided a benefit to children regardless of their sibling status. When taken together with the Huang et al. study, this suggests interactions with other children are a key component of motor development and, more importantly, the *lack* of these interactions (as experienced during the pandemic) has a detrimental effect on the developing motor system.

For many investigators, mandates restricting interpersonal interactions and closing schools resulted in a pause of their in-person research. At the same time, several authors seized on the opportunity that this provided by pivoting from in-person to on-line experimental designs. For example, Weiss et al. examined the impact of modifying program delivery from in-person to hybrid/on-line in the well-established physical activity and life skills program for girls aged 8–14 years called "Girls on the Run" (GOTR), which is an example of the type of extracurricular physical activity programming that has a positive impact on motor development as described by Gil-Mardrona et al. They surveyed over 2,000 caregivers and coaches about the impact of modified lessons, training and program delivery on the experiences and impact of the GOTR program. Caregivers and coaches reported that GOTR had a positive impact on the participants health and wellbeing in a variety of ways, despite changes in formatting due to the pandemic. Further, this research showed that the GOTR program can be successful in a variety of modalities and conditions.

Scott-Andrews et al. also used an online methodology because of the pandemic. In this study, the authors converted an in-person study to an online one. Approximately 200 families participated, and measurements of motor skills were taken using videos on motor skills, physical activity using accelerometers mailed to families, online skill perception questionnaires, and zoom interviews on beliefs about physical activity. The authors conclude that online research is possible, but several challenges needed to be addressed, including recruitment, data collection process, and data quality, among others. They concluded that researchers must develop technologies to facilitate these processes in the future.

In another study that took advantage of on-line learning, Xia et al. examined a large sample (over 45,000) of college aged participants fitness level after participating web-based physical education. Their web-based physical education program was planned to support student's health and wellbeing during the COVID-19 pandemic. This research, implemented in China, showed that during pandemic the percentage of students with "normal" weight decreased, and concomitantly, students' overall Body Mass Index rose. Further, male students' running performance decreased in 50 meters dash as well as 1 000 m run, as did female students' 800 meter running performance. Using an exceptionally large number of participants, this important study showed that physical fitness levels in college aged students decreased without appropriate support given by physical education professionals. This suggests that there is need to create feasible online physical education lessons for any future emergent threats such as a pandemic.

During the pandemic, it was recommended that people spend as much time as possible outdoors. Kjønniksen et al. investigated the effect of two outdoor school ground environments: a constructed courtyard, which offered 44 m^2 space per child, and a natural forest, which offered 50, 6 m^2 per child, on the amount of time spent in moderate to-vigorous physical activity (MVPA) of Norwegian fifth- and seventh-grade children. The two environments offered different spaces and opportunities for movement to be physically active outdoors during the school day. The results showed that on average, the children engaged in MVPA for 50 percent of the 60-min period when playing in the two environments. Further, the two different environments contributed equally to the daily amount of MVPA of the children. The findings have the potential to inform policies and programs about the value of outdoor environments in promoting recommended levels of PA among school children when indoor environments are unavailable or present health risks, such as during the pandemic.

Children's basic motor skills have been described as a milestone of their physical activity and are fundamental to healthy development, and it is imperative to have a variety of ecologically valid assessment tools that have been validated in multiple countries. Chang et al. conducted a validation study of the Canadian Agility and Movement Skill Assessment (CAMSA) test using Rash analysis with Chinese children in Zunyi Province. This assessment model is close to "real sports situations" because the required movements are consistent, continuous and extremely similar to movement practice and

is used extensively by the Canadian Assessment of Physical Literacy (CAPL). With a large number of participants (1,094 children between the ages of 9 and 12 years old), the results showed significant differences in adequacy and between genders in differential item functioning and difficulty with personal ability.

Motor performance (MP) of children is also important for active lifestyle and health and proper monitoring is important to implement specific programs. Eberhardt et al. propose a best-practice tool that can be used directly by trained teachers (fitness barometer). This tool was studied from 2012 to 2020 with children aged 6–18 years. Results showed that 12.7 percent of children were overweight or obese, and differences emerged between age groups. In 2020, the mean values of endurance and speed [$F_{(4,19,23)} = 224.81$] decreased, again demonstrating the negative impact that the COVID-19 pandemic had on physical activity levels in children.

When looking across the studies in this section, several important points are clear. First, the COVID-19 pandemic caused a major disruption in the ways everyone interacted with others both in and outside of schools. Opportunities for movement experiences in the form of physical education, sporting activities, and unstructured play were all drastically reduced for 12–24 months or more, resulting in dramatic shift in our approaches to physical activity. To that point, the body of research showed that the impact of this shift affected different individuals differently, with some groups (e.g., first born children) suffering larger delays than others. Finally, this body of research revealed some of the unique ways in which diverse groups, cultures, and countries pivoted practices to accommodate COVID restrictions and keep individuals active. The variety of experimental designs and research practices provides a strong statement for human resiliency and ingenuity promoting motor development in the midst of world-wide pandemic.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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Extracurricular Physical Activities and the Condition of Being an Only Child as a Conditioning Factor in the Psychomotor Development of 5-Year-Old Children

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In early childhood education, there is a great interdependence among motor, affective, and cognitive development. A better understanding of psychomotor development and its variables by pediatricians and those who oversee educational tasks at this stage of development, such as teachers, psychologists, counselors, and parents themselves, can influence the design of educational intervention proposals. To that effect, the present study aims to analyze the influence of some family characteristics such as the condition of being an only child or having siblings and whether the child carries out extracurricular activities linked to physical activities and sports. To achieve this objective, a Checklist of Psychomotor Activities (CPA) assessment instrument was used based on the observation of a sample of 694 children aged 5 years who were enrolled in the second cycle of child education in the province of Albacete. The results show that those children who performed extracurricular activities related to physical activities and sports had a greater development of laterality and postural tonic control than those who did not attend this type of activities. At the same time, differences were found in the affective and relational levels and in the perceptual-motor aspects in favor of children who have siblings compared with children who are only children. There is no other research that addresses both issues in the same study, and this is a strength of the present study.

Keywords: psychomotor development, infant education, physical education, extracurricular activities, only children

INTRODUCTION

Do the decisions of the parents significantly influence the development of children? This study aims to delve into two aspects that can answer this question, the number of siblings that have the children, and the type of after-school activities the children will do outside the school and how they influence the psychomotor development of 5-year-old children who are in the second cycle of early childhood education of the community of Albacete (Spain).

In the stage of early childhood education, the integral development of students is very important, because it is one of the main objectives of this educational stage. Physical education, motor activity, and psychomotricity are aspects that correlate and directly influence perceptual-motor, physical-motor, cognitive, and effective-relational development (1–4) being an important aspect in childhood inside and outside the school grounds. To know the effects of some variables on this area provides the educators tools for the improvement of psychomotor skills of children in the early stages of primary education.

Motor skills, in its systematic form, physical education, or psychomotricity in early childhood education is one of the subjects or areas that develops these aspects; however, children who carry out extracurricular activities of a sporting nature have an extra motor benefit, of which they only carry out physical activities in schools (5, 6). In turn, it is a decisive component in the parenting style, giving their children participation in extracurricular sports activities (ESAs), (7).

The benefits of ESAs carried out by children at this educational stage have a great impact on the physical, social, emotional, and psychological health of children expressed by various authors (8–10) who similarly believe that extracurricular activities facilitate the development of non-cognitive skills.

Another important variable in this research is the difference in relational psychomotor and affective skills between children who have siblings and those who do not. Authors like Berger and Nuzzo (11) have determined that children who have older siblings achieve motor skills before those older siblings; however, in number, they develop more skills and acquire these faster.

Due to the importance of the mentioned variables, the present research analyses the relevance of ESAs in the development of motor, perceptual, and affective skills and if there are differences in these skills between children who have siblings and those who have not. Next, previous studies on the two variables under study will be presented.

Extracurricular Sports Activities and Their Impact on Motor Development in Children's Education

Motor stimulation not only can benefit the physical development of 5-year-olds but in turn brings positive skills in cognitive and affective factors, since good motor development has a direct impact on perceptual, physical, motor, cognitive, and affective faculties. The work of motor patterns in early childhood is the basis for the realization of basic, as well as specialized tasks that are present in daily activities (12, 13). Motor development is characterized by being a process that is carried out throughout the development of the infant, composed of qualitative and quantitative aspects (7, 14, 15). ESAs bring cognitive benefits that are closely related to psychomotor aspects such as laterality, balance, spatial notion, perception, and postural tonic control. There are several studies that corroborate this relationship, for example.

Rasberry et al. (16) found 251 positive associations in the analysis of 43 previous studies that analyze the benefit of ESAs and its relationship to the cognitive aspects expressed through academic performance, academic behavior, cognitive skills, and student attitudes. Another reference that corroborates the benefit of the ESAs is the study carried out by Temple et al. (17), who corroborated that the most active after-school activities were associated with a higher level of motor skills. And finally, the study developed by Raudsepp and Päll (18) confirmed that performing specific activities significantly improved object control skills.

Relational Affective Factors Implicit in Extracurricular Sports Activities

The factors that influence the socialization process that are implicit in the ESAs (such as the affective factors and relational, motivational, and experiences of pleasure of acting and performing a sports activity that leads to socialization with family, colleagues, sports coaches, and teachers) bring with them not only emotional but psychological benefits as posed in the study of Bailey et al. (19). In turn, participating in an active and consenting way of expressing skills through its execution improves the social integration and brings emotional and psychomotor benefits (20).

According to Sanmartín (21), sports is recognized as an inclusive space, which will provide the individual with benefits in its psychological and social aspects. As we see, there is a conviction that habits established in the early ages will engage them significantly, marking a continuity of this style in adulthood, and also that if active lifestyles accompany healthy lifestyles, we will be able to enhance them through physical activities and sports in the early stages of childhood by encouraging the development of potentially healthy (mentally and physically) individuals.

Differences in Motor Development Between Children Who Have Siblings or Not

The children's brain is constantly learning and is highly perceptive of environmental information through movement and exploration. Related to it, is relevant to ask: is there really a difference in the motor development between children who have siblings or those who do not have siblings?

To answer this question, it is important to take into consideration that the child psychomotricity development is mediated by the environment but also this process is related to its physical constitution, namely, there are basic and egalitarian aspects in each individual; however, the speed of information processing will be different for those children who possess imitative behavior of an equal that stimulates it, not only from the motor, psychomotor, or perceptive point of view but also stimulating the various emotions that can be fostered through peer-to-peer play (22). In the same line, the order of birth in a family is also a factor that can affect the development of motor capacity.

Children with older siblings have better motor performance than only or first-born children (11, 23). It is found that one of the typical sequences is that an older child initially performs a task while the younger siblings watch or spend a lot of time

TABLE 1 | Frequency distribution and number of siblings.

N	Frequencies	% of total	% accumulated
0	132	19.0%	19.0%
1	319	46.0%	65.1%
2	195	28.1%	93.2%
3	35	5.1%	98.3%
4	10	1.4%	99.7%
6	1	0.1%	99.9%
7	1	0.1%	100.0%

TABLE 2 | Frequency distribution of after-school sports activities.

After-school activities	Frequency	% of total	% accumulated
No	250	36.0%	36.0%
Yes	444	64.0%	100.0%

observing the performance of the older sibling and replicating his/her movements (24). Older siblings provide more advanced development models for younger siblings and help to create an enriched and stimulating environment that seems to improve the development of younger siblings (22, 25). More recently, Giagazoglou et al. (26) analyzed motor development in light of the order of birth occupied by the child and concluded that this order did not have an influence on motor development.

Relational Affective Factors in Children Who Have Siblings or Not

From a psychomotor and affective-relational point of view, most studies establish that there is a significant difference between children who have older siblings and those who are an only child; from a playful point of view in motor activities, the older sibling impersonates a figure of secondary attachment, in the presence of which the younger sibling can explore the context more safely since he/she feels being accompanied and safe with him/her, or the older siblings diminish the fear of strangers, becoming a significant fraternal interaction (27). However, other studies, such as Poston and Falbo (28), mentioned that affective-relational differences are in balance between children with or without siblings of Chinese origin and in some case in some variables slightly higher in children who have siblings.

METHOD

Participants

Information has been obtained from 694 5-year-olds schooled in the third cycle of early childhood education. Information has been collected and provided by teachers from 32 child education groups, from the towns of Almansa, La Roda, Albacete, Chinchilla, Aguas Nuevas, Alcázar de San Juan, Villarobledo, Casas Ibáñez, Riópar, Munera, and Quintanar del Rey. The sample has been non-probabilistic in nature; the sampling technique has been used on purpose, as voluntary collaboration has been requested in all schools in Albacete province, and we have finally worked with the schools that agreed to participate.

TABLE 3 | Practice of extracurricular activities according to the number of siblings.

		Practice of sports extracurricular activities	
		No (%)	Yes (%)
Number of siblings	0	48	52
	1	34	66
	2	28	72
	3	31	69
	4	40	60
	6	100	0
	7	100	0

The sample consists of 46.7% girls and 53.3% boys. Most participants belong to public schools 69.5 vs. 30.5% who are students of concerted schools. It should be noted that 65% of children practice some extracurricular activities of a sporting type and 81.4% have siblings.

Instruments

The Checklist of Psychomotor Activities (CPA) was used to measure children's psychomotor development. The CPA test consists of three scales:

- Scale of Psycho-Motor Aspects (SPMA), composed of five factors or dimensions: Laterality (LAT; seven items), Dynamic Coordination (DC; six items), Tonic-Postural Control (CTP; three items), Motor Execution (ME; three items), and Balance (BAL; five items).
- Perceptual Aspects Scale (PAS), composed of five factors or dimensions: Respiratory Control (RC; three items), Body Image (BI; four items), Motor Dissociation (MD; three items), Visuo-Motor Coordination (VMC; six items), and Spatial Orientation (SO; two items).
- Scale of Socio-Emotional Aspects (SSEA), composed of two factors or dimensions: Emotional Control (EC; six items) and Social Relations (SR; five items).

Participants were evaluated by their teachers using a 5-point Likert scale from 1 (never) to 5 (always), depending on their ability to perform the proposed task on each item. The CPA has been shown to have adequate psychometric properties with good reliability (Cronbach's alpha) ranging from 0.572 (laterality) to 0.872 (balance) on the SPMA scale, between 0.514 (spatial orientation) and 0.825 (respiratory control) on the PAS scale, and between 0.572 (emotional control) and 0.800 (social relations) on the SSEA scale. Reliability considering the entire scale is remarkably high: 0.935. The authors also present evidence of factorial, content, and discriminatory validity.

Procedure

First, different schools in the province of Albacete, Spain, were contacted. An explanatory document with the objectives of the research was presented to the school's directors, and their

TABLE 4 | Mann–Whitney-test and descriptive statistics according to the practice of sports activities on the physical-motor aspects.

	Mann–Whitney-test					Descriptive statistics				
Var	***U***	***Z***	***p*-value**	***R***	**Practice**	**Mean (SD)**	**Me**	**Range**	**G1**	**G2**
LT	41,520.0	−4.250	0.000	0.167 (1)	No	25.81 (4.62)	23	294.19	0.872	−0.669
					Yes	27.42 (5.06)	27	360.27	0.043	−1.038
DC	48,986.0	−1.139	0.255	0.044	No	26.95 (3.35)	28	325.69	−1.197	0.956
					Yes	27.14 (3.22)	28	343.15	−1.193	1.189
ME	50,554.5	−0.495	0.620	0.019	No	13.83 (1.53)	15	341.69	−1.466	2.214
					Yes	13.74 (1.68)	14	334.45	−1.751	3.497
TPC	43,346.0	−3.546	0.000	0.139 (1)	No	12.59 (2.22)	13	301.89	−0.683	−0.305
					Yes	13.12 (3.07)	14	356.08	−1.231	1.881
BAL	51,440.5	−0.096	0.924	0.000	No	21.57 (3.45)	22.5	336.05	−0.628	−0.710
					Yes	21.41 (3.55)	22	337.52	−0.907	0.747
SUM	47,055.5	−1.916	0.055	0.075	No	100.75 (10.69)	103	336.05	−0.705	0.358
					Yes	102.83 (12.23)	103.5	337.52	−1.057	2.687

Significant differences $p < 0.05$.

SD, standard deviation; Me, Median; G1, skewness; G2, kurtosis; LT, laterality; DC, dynamic coordination; ME, motor execution; TPC, tonic-postural control; BAL, balance; SUM, sum of all items.

TABLE 5 | Mann–Whitney-test and descriptive statistics according to the practice of sports activities on the perceptual-motor aspects.

	Mann–Whitney-test					Descriptive statistics				
Var	***U***	***Z***	***p*-value**	***R***	**Practice**	**Mean (SD)**	**Me**	**Range**	**G1**	**G2**
RC	50,456.5	−0.528	0.597	0.020	No	13.23 (2.31)	15	342.10	−1.167	0.408
					Yes	13.08 (2.31)	14	334.23	−1.285	1.174
BI	49,840.0	−0.908	0.364	0.035	No	19.21 (1.61)	20	344.70	−3.508	17.489
					Yes	18.82 (2.59)	20	332.81	0.163	−1.651
MD	51,644.0	−0.010	0.992	0.000	No	13.59 (1.78)	14	337.09	−1.124	0.315
					Yes	13.54 (3.92)	14	336.95	−1.991	4.851
VMC	47,648.0	−1.682	0.093	0.036	No	26.04 (3.74)	27	320.05	−1.349	2.762
					Yes	26.46 (3.64)	27	346.22	−0.941	3.564
SO	45,550.5	−2.859	0.004	0.112 (1)	No	9.14 (1.11)	10	311.20	−1.228	1.073
					Yes	9.34 (1.50)	10	351.03	1.395	40.603
SUM	50,703.5	−0.401	0.689	0.015	No	81.22 (8.66)	84	332.94	−1.265	−1.665
					Yes	81.24 (9.66)	83	339.21	1.696	6.345

Significant differences $p < 0.05$.

SD, standard deviation; Me, Median; G1, skewness; G2, kurtosis; RC, respitatory control; BI, body image; MD, motor dissociation; VMC, visuo motor coordination; SO, spatial orientation; SUM, sum of all items.

voluntary participation was requested. Second, informed consent was requested from parents in schools that eventually agreed to participate; parents also answered a questionnaire asking about the other study variables: whether they have siblings and whether they do ESAs. Third, physical education teachers were training to use the CPA instrument. Fourth, the teachers in each course did the evaluation of the children with the help of a member of the research team, during an hour of physical education class. Finally, CPA evaluation data and parent questionnaires were combined into a database that was used for analysis.

Data Design and Analysis

A quantitative, non-experimental, descriptive, and explanatory cross-cutting study was carried out. It is also known as simple prospective *ex post facto* design.

Variables

The variables that have been considered to establish the comparison are family members (if you are an only child or otherwise have siblings) and education (if you do ESAs) of the participating children.

Data analyses include two parts: the first part contains the description of the variables according to their frequency and percentage distribution; the second part contains the analysis of the differences between groups that has been carried out through the non-parametric U tests of Mann–Whitney and Kruskal–Wallis.

RESULTS

Description of the Variables Analyzed

Tables 1–3 present the distribution of the variables studied. **Table 1** shows that 65% of the sample have at least one sibling,

TABLE 6 | Mann–Whitney-test and descriptive statistics according to the practice of sports activities on the affective-relational aspects.

	Mann–Whitney test					Descriptive statistics				
	U	*Z*	*p*-value	*R*	Practice	Mean (DT)	Me	Range	G1	G2
EC	50,059.0	−0.673	0.501	0.026	Yes	25.79 (4.19)	27	330.22	−1.339	2.081
					No	26.46 (3.53)	27	340.69	−1.055	4.524
SR	48,370.5	−1.382	0.167	0.054	Yes	20.67 (2.67)	21	350.91	−0.520	0.208
					No	20.51 (2.98)	21	329.44	−0.204	7.240
SUM	51,140.5	−0.219	0.827	0.000	Yes	46.46 (6.30)	48	339.22	−1.073	1.180
					No	46.97 (5.93)	47	335.79	−0.632	7.302

Significant differences $p < 0.05$.
SD, standard deviation; Me, Median; G1, skewness; G2, kurtosis; EC, emotional control; SC, social relation; SUM, sum of all items.

TABLE 7 | Mann–Whitney-test and descriptive statistics on physical-motor variables.

	Mann–Whitney-test					Descriptive statistics				
Var	*U*	*Z*	*p*-value	*r*	Siblings	Mean (SD)	Me	Range	G1	G2
LT	31,188.0	−1.797	0.072	0.167	Yes	26.25 (5.03)	24	311.02	0.872	−0.669
					No	27.00 (4.95)	26	345.40	0.043	−1.038
DC	33,403.5	−0.679	0.497	0.044	Yes	27.51 (2.65)	28	349.39	−1.233	1.348
					No	26.98 (3.38)	28	336.62	−1.150	0.858
ME	31,723.0	−1.628	0.103	0.019	Yes	14.03 (1.76)	14.5	362.73	−1.792	3.909
					No	13.72 (1.69)	14	333.57	−1.626	2.945
TPC	31,422.5	−1.714	0.087	0.139	Yes	13.26 (1.89)	13	365.12	−1.024	0.127
					No	12.87 (2.19)	14	333.03	−1.000	0.915
BAL	33,059.0	−0.857	0.391	0.000	Yes	21.81 (3.02)	22	352.13	−0.527	−0.982
					No	21.39 (3.62)	22	336.00	−0.832	0.336
SUM	33,346.0	−0.691	0.490	0.075	Yes	102.85 (10.01)	103	349.85	−0.832	−0.986
					No	101.95 (10.99)	103	336.52	0.336	1.789

Significant differences $p < 0.05$.
SD, standard deviation; Me, Median; G1, skewness; G2, kurtosis; LT, laterality; DC, dynamic coordination; ME, motor execution; TPC, tonic-postural control; BAL, balance; SUM, sum of all items.

while only 19% do not have siblings. On the other hand, in **Table 2**, it can also be observed that most children (again 65%) practice sports school activities. For its part, in **Table 3**, it is appreciated that as the number of siblings increases, the foray of students in ESAs, being only children with 52%, the least favored in this range of 0–4 siblings, however, it can be seen that 52% in front of the students have siblings or do not benefit from the relational affective stimulation that the extracurricular activities gives.

Differences Depending on the Practice of Extracurricular Sports Activities

The Mann–Whitney *U*-test results according to the practice of after-school sports activities in the physical-motor aspects are presented in **Table 4**. It is observed that there are significant differences in laterality and postural tonic control, with better performance (higher average ranges) in children who practice some extracurricular activities of sports type.

Table 5 presents the results of the Mann–Whitney-test and descriptive statistics on the perceptual-motor aspects according to the practice of extracurricular activities of sports type. In the table, it can be observed that there are only significant differences in spatial orientation, these being favorable to the group that practices extracurricular activities of sports type. In other perceptual-motor areas, there are no significant differences.

Table 6 presents the results in the affective-relational aspects. As can be seen in the table, there are no significant differences in these aspects.

Differences in Children With and Without Siblings

Table 7 presents the differences according to the presence of siblings in the family for physical-motor variables, showing that there are no significant differences between children who have siblings and those who do not have them in any physical-motor variable.

Table 8 shows the results of the Mann–Whitney-test to make differences between children who have siblings and those who do not have them in the perceptual-motor aspects. There are significant differences in spatial orientation, being favorable to the group that has no siblings. In other perceptual-motor areas,

TABLE 8 | Mann–Whitney-test and descriptive statistics on perceptual-motor variables.

	Mann–Whitney-test					Descriptive statistics				
Var	***U***	***Z***	***p*-value**	***r***	**Siblings**	**Mean (SD)**	**Me**	**Range**	**G1**	**G2**
RC	32,480.0	−1.443	0.149	0.020	Yes	13.45 (2.31)	14	356.72	−1.159	0.394
					No	13.06 (2.31)	14	334.95	−1.218	0.811
BI	30,530.5	−.742	0.458	0.035	Yes	19.46 (1.14)	20	372.19	−2.597	6.995
					No	18.84 (2.47)	20	331.41	−1.837	11.139
MD	33,045.5	−1.315	0.188	0.000	Yes	13.80 (1.44)	14	352.23	−1.209	0.878
					No	13.51 (2.00)	14	335.97	−1.746	3.556
VMC	32,133.0	−.899	0.369	0.036	Yes	26.78 (2.93)	27	359.48	−1.164	2.184
					No	26.22 (3.82)	27	334.32	−1.040	3.149
SO	33,423.0	−2.534	0.011	0.112 (1)	Yes	9.22 (1.01)	10	328.76	−1.128	0.487
					No	9.28 (1.45)	10	341.34	1.128	37.491
SUM	31,864.5	−1.190	0.234	0.015	Yes	82.72 (6.39)	84	361.61	−1.334	2.278
					No	80.91 (9.82)	83	333.83	−1.512	4.759

Significant differences $p < 0.05$.
SD, standard deviation; Me, Median; G1, skewness; G2, kurtosis; RC, respitatory control; BI, body image; MD, motor dissociation; VMC, visuo motor coordination; SO, spatial orientation; SUM, sum of all items.

TABLE 9 | Mann–Whitney-test and descriptive statistics on affective-relational variables.

	Mann–Whitney-test					Descriptive statistics				
	U	***Z***	***p*-value**	***r***	**Siblings**	**Mean (DT)**	**Me**	**Range**	**G1**	**G2**
CE	33,548.5	−0.593	0.553	0.023	Yes	26.37 (3.68)	27	348.24	−1.753	4.369
					No	26.20 (3.81)	27	336.89	−1.128	3.428
RS	29,249.5	−2.787	0.005	0.110 (1)	Yes	21.16 (2.53)	21	382.36	−0.442	0.157
					No	20.43 (2.93)	21	329.08	−0.249	6.197
SUM	31,040.5	−1.860	0.063	0.073	Yes	47.53 (5.66)	49	368.15	−1.357	3.121
					No	46.63 (6.14	47	332.33	−0.706	5.226

Significant differences $p < 0.05$.
SD, standard deviation; Me, Median; G1, skewness; G2, kurtosis; EC, emotional control; SC, social relation; SUM, sum of all items.

there are no significant differences. Finally, **Table 9** presents the results in the affective-relational aspects. There are significant differences in social relationships (higher score ranges for children who have siblings).

DISCUSSION

Many authors have investigated on ESAs, for example, Calero et al. (29), Delgado-Lobete and Montes-Montes (30), Pérez and Geidel (31), and Park et al. (32). In addition to those studies, this research proposes a global information based on the psychomotor development and the affective relational implications on this type of activities on students who have or do not have siblings. At the motor level, specifically, children have differences in laterality and postural tonic control, with better average children practicing ESAs; spatial orientation is another aspect significantly developed in children who participate in ESAs and do not have siblings. Regarding relational affective skills, this area is much nurtured by the ESAs and by the children who have siblings.

There is a belief that children who have siblings are more developed at the motor level than those who do not have siblings; however, this research determines that there are no significant differences in most of the motor physical and perceptive variables. Regarding spatial orientation, children who do not have siblings have greater stimulation in this area, since from an early age they are forced to independently explore the environment in which they are located in, which leads to greater motor development skills, unlike children who have siblings, who can learn by imitation, but will not necessarily have greater motor skills. Space orientation brings great cognitive benefits, as it is the basis for the acquisition of reading, writing, and calculation as corroborated by studies (11, 23, 24, 26), with children without siblings being more benefited academically than those with siblings. Downey (33) highlighted in his research that cognitive stimulation is lower for children who have siblings, as the resources of the parents are diluted as the family grows.

In this research, it is recognized that ESAs provide a great benefit in children who have siblings or not, being doubly benefited at the relational affective level those who have siblings, and this result coincides with those found by authors such as Vera (34) or Villalobos and Mondragón (35). The last authors conducted a comparative study of the social skills of only children and other children. They found a lower self-concept

in only children. In turn, Kitzmann et al. (36) highlighted as a result that only children are less accepted by their class group, being victimized and bullied by groups of classmates, suggesting that those with siblings better manage the conflict. Considering that these characteristics are closely related to social skills, it is affirmed that the ESAs are beneficial for only children, taking into account the outcome of this study and the other research mentioned above, since coexistence, sharing, follow-up of instructions, and collaborative learning that occurs in sports permit the children to improve their emotional development. On the other hand, possessing a habit and a recreational physical intention in which the children can use their physical skills may also strengthen their emotional development.

These results confirm, as do the research of Eime et al. (37), Fredricks and Eccles (38), Dimech and Seiler (39), or Vella et al. (40), that sports activities are beneficial to children during their development.

CONCLUSIONS, LIMITATIONS, AND FUTURE STUDIES

At the motor level, it is once again demonstrated that ESAs are beneficial for the child population. In addition, spatial orientation is an area that brings benefits that are related to cognitive development especially at those early ages in the acquisition of basic instrumental reading subjects, writing, and calculation. It is also appreciated that there are no differences between children who have siblings and those who do not at the level of laterality, postural tonic, and perceptual aspects—motor.

At the affective-relational level, it is of great benefit to all children the ESAs but more for those who do not have siblings, since it provides them with a space in which they can establish social relationships, which can sometimes deteriorate within the school, giving it a second opportunity to develop in the affective development and in the establishment of social relationships, improving their community skills, reducing anxiety and psychological difficulties, and acquiring skills for better conflict management, among others.

At the level of educational and community policies, it is necessary for communities to facilitate and promote within educational institutions, or sports institutions, access to ESAs and in this way promote a better society, stimulating the parents of only children to get into these activities, exposing the benefits to them, and providing aid plans and transfer, among others, to parents of large families who, seeing their abilities diminished, deprive children of the participation in ESAs.

Some of the limitations found in this research are that the sample is not probabilistic and not generalizable to the Spanish population; however, Castilla la Mancha region is in central Spain and can be a good reflection of the country's behavior. For future studies, it should be interesting to analyze in-depth the effects of an interventional program to see the extent to which space orientation affects the psychomotor development in both children who are only children and those with siblings. Since space orientation plays an important role in acquiring knowledge of other instrumental materials, as well as improving the affective and relational dominance of children, the intervention program may be directed to improve the spatial orientation skills in both groups.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by School Ethics and Conviction Committee CRA CALAR DEL MUNDO, Albacete, Spain. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

PG-M: research design, information gathering, and report preparation. SR-M: data analysis and report preparation. CR-F: review of the bibliography and preparation of the report. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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BRIEF RESEARCH REPORT
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Associations Between Movement Behaviors and Emotional Changes in Toddlers and Preschoolers During Early Stages of the COVID-19 Pandemic in Chile

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Background: There is limited evidence about emotional and behavioral responses in toddlers and preschoolers during the novel coronavirus (COVID-19) pandemic, particularly in Latin America.

Objective: To assess associations between changes in movement behaviors (physical activity, screen time and sleeping) and emotional changes in toddlers and preschoolers during early stages of the pandemic in Chile.

Methods: A cross-sectional study conducted from March 30th to April 27th, 2020. Main caregivers of 1- to 5-year-old children living in Chile answered an online survey that included questions about sociodemographic characteristics, changes in the child's emotions and behaviors, movement behaviors and caregivers' stress during the pandemic. Multiple linear regressions were used to assess the association between different factors and emotional changes in toddlers and preschoolers.

Results: In total, 1727 caregivers provided complete data on emotional changes for children aged 2.9 ± 1.36 years old, 47.9% girls. A large proportion of toddlers and preschoolers in Chile experienced emotional and behavioral changes. Most caregivers reported that children "were more affectionate" (78.9%), "more restless" (65.1%), and 'more frustrated' (54.1%) compared with pre-pandemic times. Apart from changes in movement behaviors, factors such as child age, caregivers' age and stress, and residential area (urban/rural) were consistently associated with changes in emotions and behaviors.

Conclusion: The pandemic substantially affected the emotions and behaviors of toddlers and preschoolers in Chile. The findings suggest that supportive actions for

caregivers may have a positive impact not only on adults but also on children. Mental health promotion programs should consider multilevel approaches in which the promotion of movement behaviors and support for caregivers should be essential pieces for future responses.

Keywords: physical activity, screen time, sleeping, emotion, coronavirus, stress, children

INTRODUCTION

The coronavirus (COVID-19) pandemic declared by the World Health Organization (WHO) in March 2020, has affected millions of people worldwide (1). Latin America has been impacted significant in terms of mortality and the spread of the disease especially during the first wave. Chile accumulated 13,944 deaths from March until October 27th 2020, placing the country seventh in the world with 74.5 deaths per 100,000 inhabitants due to COVID-19 (2).

One of the most common measures to control the spread of the virus was the introduction of mobility restrictions (i.e., lockdown) and physical distancing in the population. Despite their relevance, these measures affected a wide range of everyday life dimensions such as work, education, transport, recreation and household activities (1, 3). A large proportion of adults faced financial struggles due to job losses or suspensions, while children and adolescents experienced changes in their education, limits on their social interactions, and less access to school-based social services beyond education, such as food and health care (3, 4). These multiple challenges have likely had a negative impact not only on people's physical health but also on their psychosocial well-being (5).

Stress and social isolation are factors that affect mental and brain health (6), conditions that may be aggravated in families suffering health and economic hardships during the pandemic. Studies have shown increases in the rates of stress, depression and anxiety in adults during the COVID-19 pandemic (7–10). Children, particularly those under the age of five (11, 12) have been among the most vulnerable groups due to their reliance on others (parental, family, peer or institutional support) to cope with these challenging circumstances (7, 13, 14). During the initial stages of the pandemic, in Spain and Italy, most parents (87.5%) reported emotional and behavioral changes in children, and three out of four parents reported feeling stressed (15). In addition, children experienced more struggles in concentrating (76.6%), and were more irritable (39.0%), restless or nervous (38.0%), manifesting symptoms of loneliness (31.1%) (15). In China, children aged 3-6 were more likely to show clinginess and fear that family members may be sick due to COVID-19 compared with older children (16).

Mental health symptoms usually appear in childhood and then continue into adolescence (17–19). It may be expected to observe emotional and behavioral changes as a reaction of an adverse event like the pandemic, but these changes may also be affected by the caregivers' responses (20–23). Studies have shown that toddlers' and preschoolers' behavioral problems and hyperactivity were associated with their parents' mental health (24). Longitudinal evidence has shown that "proximal risks" such as family grief/illness events, harsh discipline, maternal emotional distress, overinvolved/protective parenting, have the most considerable effect on externalizing and internalizing symptoms of mental health in preschoolers (20). These potential risk factors may be exacerbated during the COVID-19 pandemic as most families are suffering a contextual change that has transformed family dynamics. However, more than 12 months after the declaration of the COVID-19 pandemic, limited evidence exists regarding the emotional impact on toddlers and preschoolers and how this is associated with their parents' feelings or behavioral responses.

Young children's movement behaviors (physical activity, sedentary behavior and sleep) have been negatively impacted during the pandemic (25, 26). This in turn has the potential of affecting other areas of health and development (27, 28). For example, physical activity is positively associated with psychosocial health (29) and with sociability (30). High levels of sedentary screen time during infancy has been shown to be associated with greater emotional and behavioral problems at age 4 (31) while preschoolers who met the WHO guideline for screen time had fewer emotional problems than preschoolers who did not meet the guideline (32). Shorter sleep duration has also been associated with poorer emotional regulation (33). This study aimed to evaluate the associations between changes in movement behaviors, caregivers' stress, and sociodemographic factors with emotional and behavioral responses in toddlers and preschoolers during early stages of the pandemic in Chile.

MATERIALS AND METHODS

Participants and Procedures

An online survey for main caregivers of 1- to 5-year-old children living in Chile was conducted from March 30th to April 27th, 2020. The study was promoted online using social networks (Facebook, Twitter, and Instagram), messaging apps and emails to educational institutions that targeted all regions in Chile. The inclusion criteria were: (1) living in Chile, (2) being the main caregiver of a 1- to 5-year-old child, and (3) living with the child most of the time before and during the COVID-19 pandemic. The current study presents the results derived from a second survey completed by caregivers who participated in a study which aimed to assess movement behavior changes during the pandemic. All participants gave their online informed consent to participate in the study. The study was approved by the Scientific Ethics Committee at Universidad de La Frontera, Chile (ORD.: 009-2020).

The study started 2 weeks after the Chilean government mandated that educational centers close (March 16th, 2020) due to COVID-19 and finished on April 27th, 2020, when educational centers were still closed. Data were collected and managed using REDCap (Research Electronic Data Capture) hosted at the Universidad de La Frontera (34).

Outcome

The emotional changes during the early stages of the pandemic were measured with questions developed for the context in COVID-19 pandemic. The emotions included in the study were selected from those commonly reported in the literature and used in questionnaires such as the Revised Children's Anxiety and Depression Scale (35) and the Strengths and Difficulties Questionnaire (36). The main caregivers answered the following question for ten emotions or attitudes: "During the last time in the context of the coronavirus pandemic (lockdown or isolation) the child has been/had more: affectionate/ restless/ aggressive/ irritable/ temper tantrums/ frustrated/ worried/ sad/ sensitive/ afraid?". Each question had a Likert-type response options in a 5-point scale (Strongly disagree to Strongly agree), with an additional option for "not applicable". The questionnaires were piloted in a small sample of caregivers before its official launch to assess pertinence, readability and understanding of the items. The questions related to emotional changes had a good internal consistency (Cronbach's alpha: 0.88). The questionnaire is included in the **Supplementary Material**.

Movement Behaviors

Caregivers were asked to estimate total physical activity, screen time, sleep duration on a typical day before and during early stages of the COVID-19 pandemic. Sleep quality both before and during the COVID-19 pandemic was asked using a scale from 1 to 7 in which a higher score indicated better quality. These questions were adapted from those used in the International Study of Movement Behaviors in the Early Years (SUNRISE study, www.sunrise-study.com) to capture the unique features of the pandemic (37, 38). The changes in these behaviors were calculated using a residualized change score approach to eliminate auto-correlated errors and regression toward the mean (39, 40). Thus, first, each behavior during the COVID-19 pandemic was regressed on the behavior before the COVID-19. Then, the residualized change score (i.e., trend) for each behavior was estimated as each participant's standardized residual score. A positive residualized change score indicates an increase in the specific behavior from the time before COVID-19 and a negative score indicates a decrease.

Covariates

Sociodemographic information included child's and caregiver's sex, child's and caregiver's age, caregiver's change in working condition due to the pandemic (yes/no, being fired or salary decreased), caregiver's stress during the pandemic (more irritable, more tired, having difficulties to concentrate, having difficulties to work; scale 1 to 5 [never to always]). The questions related to caregivers' stress had acceptable internal consistency (Cronbach's alpha: 0.79). The items are included in the **Supplementary Material**. Family characteristics included family income (<530 United States Dollars [USD]; ≥530–<1830 USD, ≥1830 USD), main caregiver's level of education, number of people per home, and number of children per home. Home characteristics included dwelling type (house, apartment or other), squared meters per person at home (<11.7 m^2 per person, ≥11.7 to <18.3 m^2 per person, ≥18.3 to <25 m^2 per person, and ≥25 m^2 per person), space to play at home (yes/no), living area (urban/rural) and living in an area under lockdown (yes/no).

Statistical Analysis

Mean (standard deviation, SD) and proportions were used to describe the participants' characteristics. Comparisons between participants' characteristics and outcomes by sex were performed using *t*-tests and chi-squared test. Multiple linear regressions were used to assess the association between different factors and emotional changes in toddlers and preschoolers during early stages of the COVID-19 pandemic. All models were mutually adjusted for individual, caregivers, family, home and geographic characteristics describe above. All data were analyzed using Stata 15.1 (StataCorp LLC, USA). *P*-values < 0.05 were considered statistically significant (tested 2-sided).

RESULTS

In total, 1727 caregivers provided complete data on the emotional changes in their children. The mean age was 2.9 ± 1.36 years, and comprised 47.9% girls, corresponding to a 54.7% of those who completed the first stage of this study that included questions on movement behaviors ($n = 3{,}157$). No differences were observed in the sample characteristics with the original sample. Children reduced their physical activity, increased their screen time and their sleep quality declined during the early stages of the pandemic. About 60% of caregivers were 25- to 34-years-old and about 40% experienced changes in their working conditions. On a scale from 1 to 5, with a higher score indicating a worse outcome, caregivers scored 3.4 ± 1.06 for being more irritable, 3.7 ± 1.12 for being more tired, 3.5 ± 1.18 for having difficulties in concentrating, and 3.4 (1.41) for having difficulties with work. Family characteristics were comparable with those observed in the National Census for the corresponding age group in terms of dwelling (80.6 vs. 79.7% living in a house) and living area (10.8 vs. 13.5% living in a rural area); however, the current sample was more educated (68.1 vs. 39.7% with more than 12 years of education) (41). About 80% of participants were in lockdown when the questionnaire was completed. Further details regarding the sample are shown in **Table 1**.

Emotional Changes in Toddlers and Preschoolers

Figure 1 shows the proportion of children whose parents reported emotional changes during early stages of the pandemic in Chile. Most caregivers reported that children were "more affectionate" (78.9%), "more restless" (65.1%), and "more frustrated" (54.1%) compared with pre-pandemic times. The least frequently reported emotional changes were "more sad" (23.4%), "more worried" (35.5) and "more afraid" (31.9%). The only

TABLE 1 | Sample characteristics.

Characteristic	Total (n = 1,727)	Boys (n = 900)	Girls (n = 827)	p[a]
Individual characteristics				
Age, mean years (SD)	2.9 (1.37)	2.9 (1.36)	3.0 (1.38)	0.114
Overall change, mean (SD)				
Physical activity (h/day)	−0.80 (1.65)	−0.78 (1.63)	−0.82 (1.67)	0.609
Screen time (h/day)	1.44 (1.55)	1.48 (1.60)	1.40 (1.48)	0.282
Sleep duration (h/day)	0.03 (1.62)	0.02 (1.64)	0.04 (1.60)	0.764
Sleeping quality (score 1 to 7)	−0.78 (1.64)	−0.81 (1.60)	−0.74 (1.69)	0.417
Enrolled in ECEC, yes, n (%)	1342 (77.7)	700 (77.8)	642 (77.6)	0.941
Main caregiver's characteristics				
Sex, female, *n* (%)	1,668 (96.6)	858 (95.3)	810 (97.9)	0.003
Age category, *n* (%)				
<25 y	205 (11.9)	113 (12.6)	92 (11.1)	0.700
25 to <35 y	1009 (58.4)	523 (58.1)	486 (58.8)	
35 to <45 y	486 (28.1)	252 (28.0)	234 (28.3)	
45 y and more	27 (1.6)	12 (1.3)	15 (1.8)	
Main caregiver's level of education, *n* (%)				
Incomplete high school	37 (2.1)	18 (2.0)	19 (2.3)	0.943
Complete high school	514 (29.8)	270 (30.0)	244 (29.5)	
Technical degree	210 (12.2)	112 (12.4)	98 (11.9)	
University degree	966 (55.9)	500 (55.6)	466 (56.4)	
Work changes due to pandemic, yes, *n* (%)	642 (37.2)	344 (38.2)	298 (36.0)	0.347
Stress symptoms, mean (SD), 1 to 5 scale				
More irritable	3.4 (1.06)	3.4 (1.07)	3.4 (1.05)	0.241
More tired	3.7 (1.12)	3.8 (1.09)	3.7 (1.14)	0.070
Having difficulties to concentrate	3.5 (1.18)	3.6 (1.16)	3.5 (1.18)	0.022
Having difficulties to work	3.4 (1.41)	3.4 (1.38)	3.3 (1.44)	0.011
Family characteristics				
Family income, *n* (%)				
<530 USD	526 (30.5)	264 (29.3)	262 (31.7)	0.464
≥530–<1,830 USD	878 (50.9)	460 (51.1)	418 (50.5)	
≥1,830 USD	323 (18.7)	176 (19.6)	147 (17.8)	
Number of people per home, *n* (%)				
3 or less	672 (38.9)	355 (39.4)	317 (38.3)	0.540
4	534 (30.9)	284 (31.6)	250 (30.2)	
5 or more	521 (30.2)	261 (29.0)	261 (29.0)	
Children per home, *n* (%)				
1 child	861 (49.8)	457 (50.8)	404 (48.9)	0.022
2 children	633 (36.7)	341 (37.9)	292 (35.3)	
3 or more	233 (13.5)	102 (11.3)	131 (15.9)	
Home characteristics				
Dwelling type, *n* (%)				
House	1,392 (80.6)	738 (82.0)	654 (79.1)	0.286
Apartment	283 (16.4)	138 (15.3)	145 (17.6)	
Other	52 (3.0)	24 (2.7)	28 (3.4)	
Squared meters per person at home, *n* (%)				
<11.7 m^2 per person	415 (24.0)	208 (23.1)	207 (25.0)	0.749
≥11.7 to <18.3 m^2 per person	398 (23.1)	206 (22.9)	192 (23.2)	
≥18.3 to <25 m^2 per person	415 (24.0)	218 (24.2)	197 (23.8)	
≥25 m^2 per person	499 (28.9)	268 (29.8)	231 (27.9)	
Space to play at home, yes, *n* (%)	1,604 (92.9)	835 (92.8)	769 (93.0)	0.866
Geographical characteristics				
Living area, urban, *n* (%)	1,541 (89.2)	799 (88.8)	742 (89.7)	0.527
Lockdown, yes, *n* (%)	1,356 (78.5)	703 (78.1)	653 (79.0)	0.668

[a] *P-value for the differences between boys and girls for each variable. USD, United States Dollars; SD, standard deviation.*

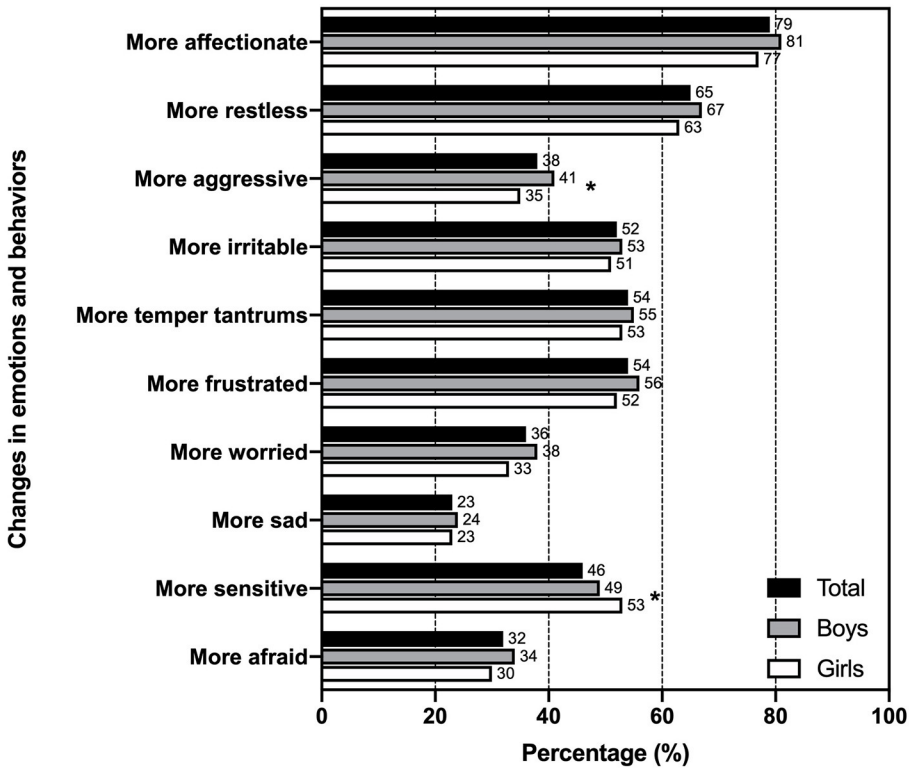

FIGURE 1 | Proportion of children that showed emotional and behavioral changes during early stages of the COVID-19 pandemic in Chile. Emotional changes were measured with a 1 to 5 scale in which 4 or more indicated change. Parents were allowed to answer "not applicable." *Indicates difference between boys and girls ($p < 0.05$).

differences according to sex were observed for "more aggressive" (40.5% in boys vs. 35.2% in girls, $p = 0.032$) and "more sensitive" (48.5% in boys vs. 52.6% in girls, $p = 0.024$).

Factors Associated With Emotional Changes in Toddlers and Preschoolers

Table 2 shows the results from the multivariable linear regression models in which different factors were associated with emotional changes in children during early stages of the COVID-19 pandemic in Chile. At the individual level, being a boy was associated with increases in aggressiveness and irritability. Older children were less likely to show increases in restlessness, irritability, temper tantrums, but at the same time they were more worried, sad and afraid than younger children.

Children whose parents reported smaller declines in physical activity levels were more affectionate and less irritable, worried, sensitive and afraid (**Table 2**). Those who had greater increases in their screen time were more likely to be more aggressive, irritable, frustrated, sensitive and have more temper tantrums. Children whose sleep duration increased were more affectionate and less aggressive, angry and sad. Children whose sleep quality was less affected were less likely to be restless, aggressive, irritable, have temper tantrums, frustrated, worried, sad, sensitive and afraid.

Caregivers who were 45 years and older reported that their children were less likely to be more restless, aggressive, irritable and had fewer temper tantrums, while caregivers who were 35 years and older reported less frustration in their children (**Table 2**). Irritability from caregivers was positively associated with all the measured emotions except for affection. Tiredness from caregivers was positively associated with aggressiveness, frustration, sadness and sensitivity, and fear. Those caregivers who reported more difficulties in concentrating had children who were more affectionate, sad and sensitive.

When observing the family characteristics (**Table 3**), those children from wealthier families were less likely to be worried and sad. Children who lived with five or more people were more restless. In contrast, those who lived with three or more children were less likely to be restless. Children who lived in homes with between 18.3 and 25 m^2 per person were less likely to be more aggressive. Those children who lived in rural areas were less restless, irritable, frustrated and sensitive, and had fewer temper tantrums. Children who were under lockdown measures were less likely to be sad and afraid.

DISCUSSION

To our knowledge, this is the first study in Latin America that has reported the impact of the pandemic on emotions and behaviors among toddlers and preschoolers. This study has shown that a large proportion of toddlers and preschoolers in Chile experienced emotional and behavioral changes during the

TABLE 2 | Child's and caregivers'characteristics associated with emotional changes in toddlers and preschoolers during early stages of the COVID-19 pandemic (n = 1,727).

Characteristic	Affectionate ß (95%CI)	Restless ß (95%CI)	Aggressive ß (95%CI)	Irritable ß (95%CI)	Temper tantrums ß (95%CI)	Frustrated ß (95%CI)	Worried ß (95%CI)	Sad ß (95%CI)	Sensitive ß (95%CI)	Afraid ß (95%CI)
Child's characteristics										
Sex (ref: girls)										
Boys	0.02 (−0.08, 0.13)	0.10 (−0.02, 0.22)	**0.24*** (0.10, 0.37)**	**0.15* (0.03, 0.28)**	0.08 (−0.05, 0.20)	0.09 (−0.03, 0.22)	0.11 (−0.01, 0.24)	0.04 (−0.08, 0.17)	0.08 (−0.05, 0.21)	0.08 (−0.05, 0.22)
Age, years	0.03 (−0.01, 0.07)	**−0.08*** (−0.13, −0.03)**	−0.03 (−0.08, 0.03)	**−0.10*** (−0.15, −0.06)**	**−0.06*** (−0.11, −0.01)**	−0.03 (−0.08, 0.02)	**0.13*** (0.08, 0.18)**	**0.11*** (0.06, 0.16)**	0.05 (0.00, 0.10)	**0.07** (0.02, 0.12)**
Change score in movement behaviors[a]										
Physical activity	**0.07* (0.01, 0.13)**	0.06 (−0.01, 0.12)	−0.01 (−0.09, 0.06)	**−0.08* (−0.15, −0.01)**	−0.04 (−0.12, 0.03)	−0.05 (−0.12, 0.02)	**−0.10** (−0.17, −0.05)**	−0.06 (−0.13, 0.01)	**−0.07* (−0.15, 0.00)**	**−0.12** (−0.20, −0.04)**
Screen time	0.01 (−0.04, 0.07)	0.06 (0.00, 0.13)	**0.12** (0.04, 0.19)**	**0.12*** (0.06, 0.19)**	**0.10** (0.03, 0.17)**	**0.13*** (0.06, 0.19)**	0.05 (−0.01, 0.12)	0.06 (−0.01, 0.13)	**0.08* (0.01, 0.15)**	0.01 (−0.07, 0.08)
Sleep duration	**0.07** (0.02, 0.12)**	−0.04 (−0.10, 0.02)	**−0.08* (−0.15, −0.02)**	−0.03 (−0.09, 0.03)	**−0.06* (−0.13, −0.00)**	−0.02 (−0.08, 0.04)	−0.04 (−0.10, 0.02)	**−0.09** (−0.15, −0.03)**	−0.06 (−0.13, 0.00)	−0.02 (−0.08, 0.05)
Sleep quality	0.04 (−0.01, 0.10)	**−0.19*** (−0.25, −0.12)**	**−0.20*** (−0.27, −0.13)**	**−0.29*** (−0.36, −0.22)**	**−0.26*** (−0.32, −0.19)**	**−0.27*** (−0.33, −0.20)**	**−0.22*** (−0.29, −0.16)**	**−0.20*** (−0.27, −0.13)**	**−0.20*** (−0.27, −0.13)**	**−0.24*** (−0.31, −0.17)**
Enrolled in ECEC (ref: no)	0.08 (−0.06, 0.22)	0.12 (−0.04, 0.28)	0.02 (−0.16, 0.20)	0.04 (−0.13, 0.21)	0.11 (−0.06, 0.29)	0.17 (−0.00, 0.33)	0.12 (−0.05, 0.29)	0.01 (−0.16, 0.19)	0.07 (−0.11, 0.25)	0.05 (−0.14, 0.23)
Caregiver's characteristics										
Age category (ref: <25 y)										
25 to <35 years	0.00 (−0.17, 0.18)	−0.04 (−0.24, 0.16)	−0.19 (−0.42, 0.04)	−0.20 (−0.41, 0.02)	−0.19 (−0.41, 0.03)	−0.19 (−0.40, 0.02)	−0.09 (−0.30, 0.13)	0.04 (−0.18, 0.26)	−0.15 (−0.38, 0.08)	0.06 (−0.18, 0.29)
35 to <45 years	−0.15 (−0.36, 0.05)	−0.09 (−0.32, 0.15)	−0.13 (−0.40, 0.14)	−0.22 (−0.47, 0.03)	−0.18 (−0.43, 0.08)	**−0.27* (−0.52, −0.02)**	−0.00 (−0.25, 0.25)	0.12 (−0.13, 0.37)	−0.22 (−0.48, 0.04)	0.10 (−0.18, 0.37)
45 years and more	−0.38 (−0.83, 0.07)	**−0.59* (−1.11, −0.08)**	**−0.60* (−1.17, −0.03)**	**−0.57* (−1.12, −0.02)**	**−0.71* (−1.27, −0.15)**	**−0.71** (−1.24, −0.18)**	−0.10 (−0.63, 0.43)	−0.10 (−0.64, 0.43)	−0.29 (−0.87, 0.28)	−0.23 (−0.83, 0.38)
Level of education (ref: incomplete high school)										
Complete high school	0.03 (−0.34, 0.39)	−0.07 (−0.48, 0.35)	0.01 (−0.46, 0.48)	0.34 (−0.10, 0.79)	−0.02 (−0.47, 0.44)	0.20 (−0.24, 0.63)	0.16 (−0.27, 0.59)	−0.16 (−0.62, 0.29)	−0.01 (−0.46, 0.43)	−0.25 (−0.73, 0.22)
Technical degree	0.08 (−0.30, 0.47)	−0.18 (−0.62, 0.26)	0.03 (−0.47, 0.52)	0.25 (−0.22, 073)	−0.03 (−0.51, 0.45)	0.26 (−0.20, 0.71)	0.16 (−0.29, 0.61)	−0.26 (−0.74, 0.21)	0.06 (−0.41, 0.53)	−0.33 (−0.83, 0.17)
University degree	0.06 (−0.31, 0.43)	−0.12 (−0.54, 0.31)	0.09 (−0.39, 0.57)	0.33 (−0.13, 0.79)	−0.01 (−0.48, 0.45)	0.31 (−0.13, 0.75)	0.19 (−0.25, 0.63)	−0.27 (−0.73, 0.20)	−0.07 (−0.53, 0.38)	−0.33 (−0.82, 0.15)
Work change (ref: no)										
Yes	−0.04 (−0.15, 0.07)	−0.09 (−0.22, 0.04)	0.00 (−0.15, 0.14)	−0.03 (−0.17, 0.10)	−0.03 (−0.17, 0.12)	0.04 (−0.10, 0.17)	0.04 (−0.09, 0.17)	0.03 (−0.11, 0.17)	0.06 (−0.08, 0.21)	0.06 (−0.09, 0.20)

(Continued)

TABLE 2 | Continued

Characteristic	Affectionate β (95%CI)	Restless β (95%CI)	Aggressive β (95%CI)	Irritable β (95%CI)	Temper tantrums β (95%CI)	Frustrated β (95%CI)	Worried β (95%CI)	Sad β (95%CI)	Sensitive β (95%CI)	Afraid β (95%CI)
Stress symptoms (1 to 5 scale)										
Irritable	0.01 (−0.05, 0.07)	**0.24*** (0.17, 0.31)**	**0.26*** (0.18, 0.34)**	**0.29*** (0.21, 0.36)**	**0.25*** (0.17, 0.33)**	**0.24*** (0.16, 0.31)**	**0.16*** (0.08, 0.24)**	**0.16*** (0.08, 0.24)**	**0.21*** (0.13, 0.29)**	**0.19*** (0.11, 0.28)**
Tired	−0.01 (−0.08, 0.05)	0.04 (−0.03, 0.11)	**0.10* (0.02, 0.18)**	0.08 (0.00, 0.15)	0.07 (−0.01, 0.15)	**0.09* (0.01, 0.17)**	0.05 (−0.03, 0.13)	0.02 (−0.07, 0.10)	−0.05 (−0.14, 0.03)	−0.02 (−0.11, 0.06)
Difficulties to concentrate	**0.07* (0.01, 0.13)**	0.06 (−0.01, 0.13)	0.02 (−0.06, 0.10)	0.04 (−0.04, 0.12)	0.04 (−0.04, 0.12)	0.06 (−0.02, 0.13)	0.04 (−0.03, 0.12)	**0.08* (0.00, 0.16)**	**0.18*** (0.10, 0.26)**	0.07 (−0.01, 0.16)
Difficulties to work	0.00 (−0.05, 0.04)	−0.01 (−0.06, 0.04)	0.04 (−0.02, 0.09)	0.00 (−0.05, 0.05)	0.01 (−0.04, 0.07)	0.00 (−0.06, 0.05)	0.01 (−0.04, 0.07)	0.02 (−0.04, 0.07)	0.03 (−0.03, 0.08)	0.05 (−0.01, 0.10)

[a]standardized residualized change score between the behavior before and during the pandemic.
Emotions were in a scale from 1 to 5, participants had the chance to select not applicable.
Each model was adjusted by individual, caregiver's, family, home and geographical characteristics, including region.
*Significance: *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.*
Bold numbers indicate statistical significance.

early stages of the COVID-19 pandemic. Several variables were consistently associated with emotional changes such as the child's age, changes in movement behaviors in the child, caregivers' age, caregiver's irritability, and residential area. Some family and home characteristics such as family income and number of inhabitants per home were also associated with emotional changes but less consistently than the other factors. The presence of lockdown was inversely associated with children being more sad and afraid.

Our study showed that during the early stages of the pandemic child's and caregiver's characteristics were more consistently associated with emotional changes in toddlers and preschoolers than family, home and geographic characteristics. As shown in other studies (29–33), physical activity, screen time and sleep duration and quality were associated with emotions in children, highlighting the importance of ensuring opportunities to maintain healthy movement behaviors. These results capture early stages of the pandemic. Therefore, some of these associations may have changed as the restrictions to mobility mandated in Chile to control the spread of the virus were maintained for the remainder of 2020. The negative effect on healthy levels of movement behaviors and the stress associated with the restrictions may have negative effects not only on the emotional health but also cognitive development in children (42, 43). In line with international recommendations (27, 44), these findings suggest that healthy movement behaviors should be a key response to support psychosocial health in early childhood and prevent other deleterious effects of the pandemic.

Among the caregiver's characteristics, the study showed associations between caregivers' irritability, tiredness and difficulties in concentrating with changes in children's emotions and behaviors. Other studies have reported how parental distress has been associated with children's emotions and behaviors during the COVID-19 pandemic (45, 46). During the first months of the pandemic, our results show that changes in working conditions for the caregivers were not associated with emotional responses in children, but this may have changed as the COVID-19 pandemic progressed. Several family and home characteristics were associated with emotional changes in toddlers and preschoolers, highlighting the importance that emotional support from caregivers is to young children. These findings reinforce the need for implementing supportive strategies for caregivers as most of them reported increases in emotional stress, which is likely to be maintained or worsened as the pandemic continues (47). Programs should be supportive not only at individual level but also through comprehensive approaches in which communities, employers and decision-makers should understand and empathize with caregivers (mainly women in Chile). A model similar to that used in the "Sistema Distrital del Cuidado" (District system of care in English) in Bogotá (48), Colombia, that was developed prior to the COVID-19 pandemic, may be used as a starting point as it focused on providing opportunities for reducing the burden of care, particularly in women, while offering educational and health care activities, among others, for the users.

Living in rural areas was frequently associated with fewer emotional changes in children. During the COVID-19 pandemic,

TABLE 3 | Family, home and geopolitical characteristics associated with emotional changes in toddlers and preschoolers during early stages of the COVID-19 pandemic (n = 1,727).

Characteristic	Affectionate ß (95%CI)	Restless ß (95%CI)	Aggressive ß (95%CI)	Irritable ß (95%CI)	Temper tantrums ß (95%CI)	Frustrated ß (95%CI)	Worried ß (95%CI)	Sad ß (95%CI)	Sensitive ß (95%CI)	Afraid ß (95%CI)
Family characteristics										
Family income (ref: <530 USD)										
≥530-<1,830 USD	0.02 (−0.11, 0.16)	−0.09 (−0.25, 0.07)	−0.08 (−0.26, 0.09)	−0.04 (−0.20, 0.13)	0.02 (−0.15, 0.19)	−0.11 (−0.28, 0.05)	−0.13 (−0.29, 0.03)	−0.12 (−0.29, 0.04)	−0.06 (−0.23, 0.12)	−0.03 (−0.21, 0.14)
≥1830 USD	−0.07 (−0.26, 0.12)	−0.19 (−0.41, 0.03)	−0.21 (−0.46, 0.04)	−0.19 (−0.42, 0.04)	0.04 (−0.20, 0.28)	−0.17 (−0.40, 0.06)	**−0.26* (−0.49, −0.03)**	**−0.35** (−0.58, −0.12)**	−0.20 (−0.44, 0.04)	−0.23 (−0.48, 0.01)
Number of people per home (ref: 3 or less)										
4	0.09 (−0.07, 0.26)	0.17 (−0.02, 0.36)	0.03 (−0.19, 0.24)	0.18 (−0.02, 0.38)	0.05 (−0.15, 0.26)	0.05 (−0.15, 0.25)	0.01 (−0.19, 0.21)	0.01 (−0.19, 0.21)	−0.07 (−0.28, 0.14)	0.04 (−0.17, 0.25)
5 or more	0.08 (−0.10, 0.25)	**0.25* (0.05, 0.44)**	0.07 (−0.15, 0.30)	0.10 (−0.11, 0.31)	0.13 (−0.08, 0.35)	0.08 (−0.13, 0.29)	0.09 (−0.12, 0.29)	0.00 (−0.21, 0.21)	−0.11 (−0.33, 0.11)	0.05 (−0.17, 0.28)
Children per home (ref: 1 child)										
2 children	−0.04 (−0.19, 0.11)	−0.04 (−0.21, 0.13)	0.16 (−0.04, 0.35)	−0.03 (−0.21, 0.15)	0.03 (−0.16, 0.22)	0.06 (−0.12, 0.24)	0.15 (−0.03, 0.33)	0.17 (−0.01, 0.35)	0.07 (−0.12, 0.26)	0.02 (−0.17, 0.21)
3 or more	−0.05 (−0.25, 0.15)	**−0.25* (−0.48, −0.01)**	0.04 (−0.23, 0.30)	0.05 (−0.20, 0.30)	−0.02 (−0.27, 0.23)	0.02 (−0.23, 0.27)	0.03 (−0.21, 0.28)	0.06 (−0.19, 0.31)	0.18 (−0.08, 0.44)	0.01 (−0.26, 0.27)
Home characteristics										
Dwelling type (ref: house)										
Apartment	0.13 (−0.02, 0.28)	0.11 (−0.06, 0.29)	−0.07 (−0.26, 0.13)	0.00 (−0.18, 0.18)	−0.03 (−0.22, 0.15)	0.03 (−0.15, 0.21)	0.01 (−0.17, 0.19)	0.08 (−0.11, 0.26)	0.08 (−0.11, 0.27)	−0.02 (−0.22, 0.17)
Other	0.09 (−0.22, 0.39)	0.14 (−0.22, 0.49)	0.29 (−0.12, 0.69)	0.26 (−0.11, 0.63)	0.19 (−0.18, 0.57)	0.30 (−0.07, 0.67)	0.01 (−0.35, 0.38)	0.05 (−0.33, 0.44)	0.08 (−0.31, 0.47)	0.33 (−0.06, 0.73)
Squared meters per person at home (ref: <11.7 m^2 per person)										
≥11.7 to <18.3 m^2 per person	0.02 (−0.13, 0.18)	−0.03 (−0.21, 0.14)	0.00 (−0.20, 0.20)	−0.13 (−0.32, 0.06)	−0.05 (−0.24, 0.14)	−0.06 (−0.25, 0.13)	−0.01 (−0.20, 0.18)	0.02 (−0.17, 0.21)	−0.09 (−0.29, 0.10)	0.05 (−0.15, 0.26)
≥18.3 to <25 m^2 per person	0.09 (−0.08, 0.26)	0.09 (−0.11, 0.28)	**0.24* (0.02, 0.46)**	0.16 (−0.04, 0.37)	0.21 (0.00, 0.41)	0.16 (−0.04, 0.37)	0.02 (−0.18, 0.22)	0.08 (−0.12, 0.29)	0.04 (−0.17, 0.26)	0.09 (−0.12, 0.31)
≥25 m^2 per person	0.02 (−0.16, 0.20)	0.06 (−0.15, 0.26)	0.19 (−0.04, 0.43)	0.16 (−0.06, 0.38)	0.09 (−0.13, 0.31)	0.13 (−0.08, 0.35)	0.09 (−0.13, 0.30)	0.08 (−0.14, 0.30)	−0.05 (−0.28, 0.18)	0.09 (−0.15, 0.32)
Space to play at home (ref: no)										
Yes	0.19 (−0.02, 0.40)	−0.12 (−0.35, 0.12)	−0.02 (−0.28, 0.24)	−0.20 (−0.45, 0.05)	−0.29 (−0.54, −0.03)	−0.23 (−0.48, 0.01)	−0.04 (−0.28, 0.21)	0.02 (−0.23, 0.27)	−0.19 (−0.46, 0.07)	−0.09 (−0.35, 0.18)

(Continued)

TABLE 3 | Continued

Characteristic	Affectionate β (95%CI)	Restless β (95%CI)	Aggressive β (95%CI)	Irritable β (95%CI)	Temper tantrums β (95%CI)	Frustrated β (95%CI)	Worried β (95%CI)	Sad β (95%CI)	Sensitive β (95%CI)	Afraid β (95%CI)
Geographical characteristics										
Area (ref: urban)										
Rural	−0.09 (−0.26, 0.08)	**−0.32** (−0.52, −0.13)**	−0.22 (−0.44, 0.00)	**−0.23* (−0.43, −0.02)**	**−0.23** (−0.44, −0.02)**	**−0.28* (−0.48, −0.07)**	0.08 (−0.13, 0.28)	−0.07 (−0.28, 0.14)	**−0.27* (−0.48, −0.05)**	−0.06 (−0.28, 0.16)
Lockdown (ref: no)										
Yes	0.00 (−0.12, 0.13)	−0.01 (−0.15, 0.14)	−0.11 (−0.28, 0.05)	−0.10 (−0.25, 0.06)	−0.12 (−0.27, 0.04)	−0.09 (−0.24, 0.06)	−0.11 (−0.26, 0.04)	**−0.23** (−0.39, −0.08)**	−0.01 (−0.17, 0.15)	**−0.24** (−0.40, −0.08)**

Coefficients are standardized residualized change score between the behavior before and during the pandemic.
Emotions were in a scale from 1 to 5, participants had the chance to select not applicable.
Each model was adjusted by individual, caregiver's, family, home and geographical characteristics, including region.
*Significance: ** = $p < 0.01$; * = $p < 0.05$.*
Bold numbers indicate statistical significance.

living in rural areas was also reported as a factor positively related to smaller decreases in physical activity, declines in sleep quality and increases in screen time (25). In this context, a study conducted in 14 countries showed that preschoolers who were able to go outside during the pandemic were more likely to meet the PA guidelines (26). To compensate for the lack of opportunity for some children who live in urban areas, strategies should provide opportunities to access green spaces or open spaces to play in cities while considering physical distancing due to the pandemic. This is particularly relevant in countries like Chile in which the opening of public and national parks has been postponed for months during the pandemic, whereas commercial areas have remained opened (49). As green spaces enhance well-being, overall health and cognitive development in children (50–53) and children who live further from green spaces are more sedentary and have poorer mental health (54), it is critical to find ways for children and families to access such spaces during the pandemic. Actions to promote healthy movement behaviors in urban areas such as open streets programs should be implemented to mitigate the lack of access to green and open spaces observed in most places not only during the pandemic but also in potential post-pandemic times (55, 56).

We acknowledge that more factors may contribute to the emotional and behavioral changes during the pandemic. Strategies to mitigate the negative socioemotional issues derived from the pandemic should include multilevel approaches for promoting more physical activity, less screen time and more and better sleep quality (25, 57). Policies must consider toddlers and preschoolers in their design. The length of the pandemic in terms of the age of the child is likely to have a considerable impact on their future development compared with adults (43, 57, 58). More effort is required to manage the collateral effects of the pandemic on mental health. A report from WHO showed that a large proportion of member states have mental health and psychological support plans, but only about a fifth of them have secured additional funding for covering the activities (1). Considering the benefits of healthy levels of physical activity, sedentary behavior and sleep on socioemotional health, we recommend governments, institutions and professionals secure funding and implement supportive strategies for caregivers, early childhood education and care services, and town planners to facilitate healthier behaviors in toddlers and preschoolers.

Strengths and Limitations

Our study has explored the emotional and behavioral changes in toddlers and preschoolers using a socio ecological perspective, including the main caregiver's distress. This is critical in a pandemic context in which supporting networks (educational community, childcare services, families, friends) are more limited and caring responsibilities rely on fewer individuals. Although this was a cross-sectional study, under the circumstances of a natural experiment, we have provided evidence on a topic that is not frequently explored in movement behaviors, which is mainly focused on physical health (59). However, there are limitations in our study. The cross-sectional design of the study limits its ability to draw conclusions about causality. Also, the self- and proxy-reports used in this study may have

been affected by different sources of bias such as recall or social desirability. Our study may have recruited caregivers who would have been more concerned regarding their family's health, including emotions and movement behaviors, affecting the composition of our sample. Although we used commonly used and freely available social networks to recruit participants throughout the entire country, the final sample was not entirely representative. The sample was more educated than that observed in the census for the same age group, but it was comparable in terms of dwelling type and living area (41). We recruited a large sample, but unfortunately only 55% completed the questionnaire. However, the characteristics of the sample of the current study were not different from those who completed the section on movement behaviors (25). The lower participation can be explained by people being more reluctant to provide personal information through online methods compared with face-to-face methodologies. We used the best possible option to measure the variables included in the study as strict health and ethical restrictions were mandated during the early stages of the pandemic (60) limiting, for example, the use of accelerometers or other instruments that may have required contact with participants. To overcome some of these limitations, ongoing studies should explore longitudinal associations between different exposure variables and mental health outcomes.

CONCLUSIONS

The study showed that a large of proportion of toddlers and preschoolers in Chile showed negative emotional and behavioral changes during the early stages of the COVID-19 pandemic. These changes were associated with factors such as the child's age, a decrease in physical activity and sleep duration, an increase in screen time and a decline in sleep quality. Caregivers' characteristics, including age and irritability, were also associated with child's emotional changes during the pandemic. Living in rural areas was associated with less marked changes in emotions and behaviors. Mental health promotion programs should consider comprehensive and multilevel approaches in which promoting healthy levels of movement behaviors should be an essential intervention strategy. The findings suggest that supportive actions for caregivers may have a positive impact not only on adults but also on children. Governments should highlight the importance of healthy movement behaviors in their messages and actions during and post-pandemic through strong campaigns and through supporting environmental changes to facilitate more physical activity, less screen time and more and better sleep in toddlers and preschoolers.

DATA AVAILABILITY STATEMENT

The anonymised and raw data supporting the conclusions of this article will be made available by the corresponding author, upon reasonable request.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Scientific Ethics Committee at Universidad de La Frontera, Chile (ORD.: 009-2020). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NA-F, PM-F, MT-V, AC-O'R, SM-M, and BP: conceptualization. NA-F, PM-F, MT-V, SM-M, CC-M, FR-R, and AC-O'R: methodology and investigation. MT-V and NA-F: software and validation. NA-F: formal analysis, data curation, writing—original draft preparation, and visualization. NA-F and PM-F: resources, project administration, and funding acquisition. NA-F, PM-F, and AO: supervision. All authors writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.667362/full#supplementary-material

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Association Between the COVID-19 Pandemic and Infant Neurodevelopment: A Comparison Before and During COVID-19

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Aim: To investigate the association between the experience of the coronavirus disease 2019 (COVID-19) pandemic and neurodevelopment of 6-month-old and 1-year-old children and explore the differences in the association by birth order.

Methods: This comparison study was embedded in the Born in Guangzhou Cohort Study in China. The exposed group included 546 6-month-old and 285 1-year-old children who attended neurodevelopment assessments between March 1 and May 15, 2020, and the non-exposed group included 3,009 6-month-old and 2,214 1-year-old children during the same months from 2015 to 2019. Neurodevelopment at age 6 months and 1 year was assessed by trained clinical staff using the Ages and Stages Questionnaires, third edition (ASQ-3) and the Gesell Developmental Schedules (GDS).

Results: The experience of the pandemic in 2020 was associated with a higher risk of delay in the fine motor (adjusted OR: 2.50, 95% CI: 1.25, 4.99; estimated by logistic regression) and communication (adjusted RR [aRR]: 1.13, 95% CI: 1.02, 1.25; estimated by log-binomial regression) domains at age 1 year. The association between the experience of the pandemic and communication delay at age 1 year only existed in first-born children (aRR: 1.15, 95% CI: 1.03, 1.30) but not in later-born children (aRR: 1.02, 95% CI: 0.84, 1.25). No associations were observed in any domain among 6-month-olds.

Conclusion: Experiencing the COVID-19 pandemic and related public health strategies might be associated with a higher risk of delay in the development of fine motor and communication in 1-year-old children; the association observed in the communication domain only existed in first-born children.

Keywords: COVID-19 pandemic, child development, infant behavior, social isolation, observational study

INTRODUCTION

The pandemic of COVID-19 (coronavirus disease 2019; the pathogen called SARS-CoV-2, formerly 2019-nCoV) emerged in December 2019 in Wuhan, China (1, 2). As of May 25, 2020, there had been 5,304,772 confirmed cases and 342,029 deaths globally, including 84,536 confirmed cases and 4,645 deaths in China (3). A series of non-pharmaceutical intervention-based public health strategies have been applied in China to control the spread of COVID-19, including isolating confirmed cases, contact tracing, quarantine of exposed persons, travel restrictions, school and workplace closures, cancellation of mass gatherings, etc. (4). While such strategies have effectively controlled COVID-19 transmission across China and substantially reduced the number of cases (4), it has been suggested that these strategies may be associated with poorer mental health and development of school-aged children and adolescents (5–7). However, whether this association exists among children at a younger age (e.g., infants) has not been investigated.

A range of biological and psychosocial factors, such as maternal physical and mental health, physical activity, socioeconomic status, and family context, are associated with child neurodevelopment (8, 9). During the COVID-19 pandemic, the implementation of containment strategies reduces children's outdoor activities and their opportunities to contact people other than their family members. Staying indoor may also increase the screen time of the children and their family members (10). Moreover, the pandemic has led to increased anxiety and depression in the population (11), and mental health issues of parents and caregivers may have negative impacts on child development (12).

It is also suggested that neurodevelopment between first-born and later-born children may be different (13). First-born and later-born children may react differently during the COVID-19 pandemic. As two-child families have become increasingly common in China due to the relaxation of the one-child policy, it is worth studying the association between the experience of the COVID-19 pandemic and the neurodevelopment in first-born and second-born children.

As a megacity with a population of over 15,000,000 (14), Guangzhou has also been influenced by the COVID-19 pandemic. Following the lockdown of Wuhan and other cities in Hubei province from January 23, residents in Guangzhou had been encouraged to reduce outdoor activities and maintain social distancing. As mentioned above, the experience of public health strategies in response to COVID-19 might potentially influence child neurodevelopment in several ways. Investigating the association of this experience with infant neurodevelopment can help comprehensively evaluate the influence of COVID-19 and the associated strategies on the population and inform public health policies for both infectious disease control and child health in the future. The aim of the present study was to investigate the association between the experience of the COVID-19 pandemic and neurodevelopment of children aged 6 months and 1 year and explore the differences in the association by birth order.

METHODS

Study Population

This comparison analysis was part of the Born in Guangzhou Cohort Study (BIGCS), an ongoing prospective birth cohort conducted in the Guangzhou Women and Children's Medical Center (GWCMC), China. Details of the BIGCS have been described elsewhere (15). In brief, women were recruited during their first routine antenatal examinations in early pregnancy (<20 weeks of gestation, normally at around 16 weeks) at two campuses of the GWCMC, and followed up in mid- (at 24–28 weeks) and late pregnancy (at 35–38 weeks). After delivery, the women and their children were followed up at 6 weeks, 6, 12, 24, and 36 months postpartum. The protocol of the BIGCS was approved by the Institutional Ethics Committee of the GWCMC. All participants provided written informed consent at the time of recruitment.

The routine follow-up of the BIGCS had been suspended since the outbreak of COVID-19 in late January and was resumed on March 1, 2020. The present study included the children who attended the neurodevelopmental assessment at the 6-month or 1-year follow-up during March 1–May 15, 2020, as the exposed group, and those during the same months from 2015 to 2019 as the non-exposed group. Children were excluded if they withdrew before the present study, had multiple births, were preterm births (defined as gestational weeks at birth <37), had birth hypoxia (defined as Apgar score ≤7 at either 1 or 5 min), or had birth defects that might affect neurodevelopmental outcomes (including major birth defects and anomalies that affect language and motor functions). The flowchart for the selection process of the present study is shown in **Figure 1**.

Assessment of Neurodevelopment

Children's neurodevelopment at the 6-month and 1-year follow-up was assessed by clinical staff using the Ages and Stages Questionnaires, third edition (ASQ-3) and the Gesell Developmental Schedules (GDS), respectively. Before the field work, all clinical evaluators had attended training courses accredited by the official providers of these assessment tools. All assessments were conducted strictly following the instruction manuals. Regular training and quality control sessions were held by the BIGCS team to perform live examinations for each evaluator, monitor any potential assessment errors, and review all the assessment results to ensure internal consistency and data quality.

GDS

The GDS was used to evaluate the developmental quotient (DQ) in children's adaptive (i.e., cognitive), gross motor, fine motor, language (i.e., communication), and personal-social domains at the 1-year follow-up (16). The Chinese version of the GDS has been validated and adopted by the Chinese Pediatric Association (17, 18). The sum of adaptive, language and personal-social DQ was significantly correlated to the mental development index of Bayley Scales of Infant Development (BSID, $r = 0.75$, $P < 0.0001$), and the sum of gross motor and fine motor DQ was significantly correlated to the psychomotor development index

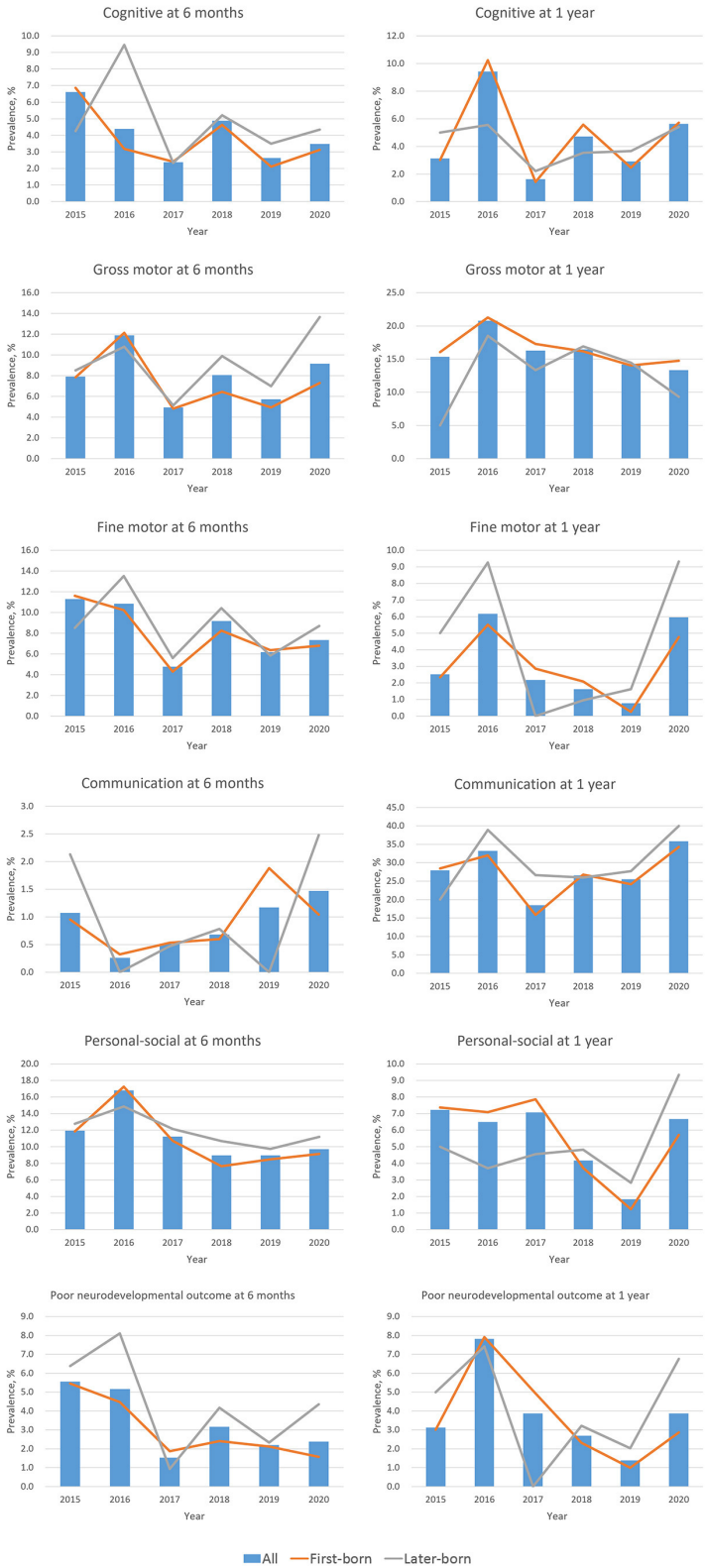

FIGURE 1 | Secular trend for the prevalence of neurodevelopmental delay at age 6 months and 1 year. Neurodevelopment was measured by the Ages & Stages Questionnaires, 3rd Edition (ASQ-3) at age 6 months, and by the Gesell Developmental Schedule (GDS) at age 1 year. Poor neurodevelopmental outcome was defined as developmental delay in more than two domains.

of BSID ($r = 0.55$, $P < 0.05$) (19, 20). Higher DQ reflects better neurodevelopmental performance. As with other child development studies using the Chinese version of GDS, we defined developmental delay in each domain as DQ < 86 (21–23). To use a composite indicator to reflect the severity of adverse developmental outcomes across all five domains in the present study, we defined "poor neurodevelopmental outcome" as developmental delay in more than two domains on the GDS.

ASQ-3

The ASQ-3 is a comprehensive standardized developmental monitoring tool for children from 1 to 66 months of age. At the 6-month follow-up, the ASQ-3 was administered by trained psychological evaluators at the GWCMC's child health care clinics. Similar to the GDS, it also assesses the following five developmental domains: communication, gross motor, fine motor, problem-solving (i.e., cognitive), and personal-social, with the cutoffs for developmental delay varying across different domains and ages (24, 25). The ASQ-3 has generally high internal consistency, test-rest reliability, and acceptable sensitivity in the Chinese population (26). To be consistent with the results from the GDS, "poor neurodevelopmental outcome" on the ASQ-3 was also defined as developmental delay in more than two domains.

Other Variables

Information on a range of maternal and child characteristics was collected from questionnaires or medical records from early pregnancy to age 1 year of the children. Maternal characteristics included age at conception (in years), monthly income (<1,500, 1,500–4,500, 4,501–9,000, or ≥9,001 yuan, based on the individual income tax brackets implemented since January 1, 2012), education level (high school or below, college, undergraduate, or postgraduate), tobacco exposure in early pregnancy (yes/no), pre-pregnancy body mass index (BMI, calculated as pre-pregnancy weight in kilogram divided by squared height in meter), gestational diabetes mellitus (GDM, yes/no), hypertensive disorders of pregnancy (HDP, yes/no), depressive symptoms in early pregnancy (Self-rating Depression Scale score ≥53) (27, 28), anxiety symptoms in early pregnancy (Self-rating Anxiety Scale score ≥50) (29, 30), and depressive symptoms at 6 months or 1 year postpartum (Edinburgh Postnatal Depression Scale score ≥13) (31). Child characteristics at birth included gestational age at birth (in weeks), child sex (male/female), birth order (1 or >1), birth weight z-score (calculated based on the INTERGROWTH-21st standards) (32), delivery mode (vaginal birth or cesarean section). Child characteristics at age 6 months or 1 year included child age (in months), duration of breastfeeding (in days), number of other children living together (0 or >0), and anthropometric indicators including BMI (calculated as children's weight in kilogram divided by squared height in meter) and head circumference, both calculated as z-scores based on the standards from the World Health Organization (33).

Statistical Analyses

Descriptive statistics, i.e., mean (standard deviation) and frequencies (percentages), were reported for all maternal and child characteristics. For both ages, the prevalence of delay in each domain and "poor neurodevelopmental outcome" was presented by year. χ^2-test was used to compare the prevalence of developmental delay in different years.

The associations between the experience of the COVID-19 pandemic (i.e., the year 2020 vs. 2015–2019) and the risk of neurodevelopmental delay at age 6 months and 1 year were examined using log-binomial regression (for the outcomes with a prevalence ≥15%, e.g., developmental delay in the gross motor and the communication domains at age 1 year, shown as relative risk [RR]) and logistic regression (for all other outcomes, shown as odds ratio [OR]), respectively. The models were adjusted for maternal age, education level, monthly income, delivery mode, child sex, birth order, birth weight z-score, breastfeeding duration, BMI z-score, head circumference z-score, and maternal postpartum depressive symptoms. Selection of the covariates is based on the following considerations: firstly, we took into account maternal demographic and socioeconomic factors (represented by maternal age, education level, and monthly income), which have been shown to be associated with child development; (34, 35) secondly, children's developmental outcomes might also differ by some factors at delivery, such as delivery mode, child sex, and birth order; (13, 36, 37) thirdly, birth weight z-score, breastfeeding duration, BMI z-score, and head circumference z-score generally reflect the child's intrauterine and postnatal growth and nutritional status, which are important factors related to neurodevelopment; (38) lastly, maternal postpartum mental illness (e.g., postpartum depression) was also considered, as evidence has suggested that it might have negative impacts on infants' developmental outcomes (39). Moreover, stratification analyses by birth order were also performed to explore the association between the experience of the COVID-19 pandemic and neurodevelopmental outcomes in first-born and later-born children.

Two-sided $P < 0.05$ was considered statistically significant. All analyses were performed using SAS 9.3 software (SAS Institute, Cary, NC, USA).

RESULTS

The flowchart for selecting the study population is shown in **Supplementary Figure 1**. Between March 1 and May 15 from 2015 to 2020, a total of 3,937 children in the BIGCS attended neurodevelopment assessments at around 6 months of age. After excluding those who withdrew before the present study ($N = 10$), were multiple births ($N = 147$), were preterm births ($N = 182$), had hypoxia at birth ($N = 18$), had neurodevelopment-related birth defects ($N = 25$), there were 3,555 children included in the analysis for the 6-month follow-up. During the same period, a total of 2,777 children in the BIGCS attended neurodevelopment assessments at around 1 year of age. We excluded those who withdrew before the present study ($N = 5$), were multiple births ($N = 105$), were preterm births ($N = 121$), had hypoxia at birth ($N = 15$), had neurodevelopment-related birth defects ($N = 32$), resulting in 2,499 children included in the analysis for the 1-year follow-up. Among those who remained in the analysis,

TABLE 1 | Maternal and child characteristics by year.

	Age 6 months				Age 1 year			
	Total (*N* = 3,555)	**2015–2019 (*N* = 3,009)**	**2020 (*N* = 546)**	**P**	**Total (*N* = 2,499)**	**2015–2019 (*N* = 2,214)**	**2020 (*N* = 285)**	**P**
Maternal characteristics								
Age at conception (years), mean (SD)	30.3 (3.9)	30.3 (3.9)	30.1 (3.8)	0.414	30.2 (3.8)	30.2 (3.8)	30.2 (3.6)	0.89
Monthly income (yuan), *n (%)*				<0.001				<0.001
≤1,500	307 (9.0)	274 (9.3)	33 (6.0)		209 (8.4)	193 (8.8)	16 (5.6)	
1,501–4,500	631 (18.5)	584 (19.8)	47 (8.6)		502 (20.3)	465 (21.2)	37 (13.1)	
4,501–9,000	1,405 (41.2)	1,225 (41.5)	180 (33.0)		1,043 (42.2)	923 (42.1)	120 (42.4)	
≥9,001	927 (27.2)	747 (25.3)	180 (33.0)		628 (25.4)	534 (24.4)	94 (33.2)	
Refused to answer	143 (4.2)	118 (4.0)	106 (19.4)		92 (3.7)	76 (3.5)	16 (5.6)	
Education level, *n (%)*				<0.001				0.029
High school or below	286 (8.0)	254 (8.4)	32 (5.9)		185 (7.4)	173 (7.8)	12 (4.2)	
College	763 (21.5)	651 (21.6)	112 (20.5)		545 (21.8)	497 (22.4)	48 (16.8)	
Undergraduate	2,025 (57.0)	1,709 (56.8)	316 (57.9)		1,405 (56.2)	1,220 (55.1)	185 (64.9)	
Postgraduate	481 (13.5)	395 (13.1)	86 (15.7)		364 (14.6)	324 (14.6)	40 (14.0)	
Tobacco exposure in early pregnancy, *n (%)*	936 (27.4)	817 (27.7)	119 (25.6)	0.311	734 (29.7)	664 (30.3)	70 (24.9)	0.043
Pre-pregnancy body mass index (kg/m^2), *n (%)*				0.369				0.707
<18.5	697 (21.2)	601 (21.1)	96 (21.5)		507 (20.9)	456 (21.3)	51 (18.3)	
18.5–23.9	2,220 (67.4)	1,917 (67.3)	303 (67.9)		1,645 (68.0)	1,447 (67.6)	198 (71.0)	
≥24.0	376 (11.4)	329 (11.6)	47 (10.5)		268 (11.1)	238 (11.1)	30 (10.8)	
Gestational diabetes mellitus, *n (%)*	541 (15.4)	457 (15.4)	84 (15.5)	0.949	382 (15.6)	336 (15.5)	46 (16.3)	0.707
Hypertensive disorders of pregnancy, *n (%)*	114 (3.2)	88 (2.8)	32 (5.9)	<0.001	86 (3.5)	80 (3.7)	6 (2.1)	0.178
With depressive symptoms in early pregnancy, *n (%)*	686 (20.5)	581 (20. 1)	105 (22.9)	0.148	527 (21.7)	463 (21.6)	64 (22.8)	0.632
With anxiety symptoms in early pregnancy, *n (%)*	446 (13.3)	388 (13.4)	58 (12.6)	0.645	348 (14.3)	301 (14.0)	47 (16.7)	0.202
With postpartum depressive symptoms at the time of child neurodevelopment assessment, *n (%)*	599 (17.8)	507 (17.6)	92 (19.1)	0.398	380 (16.0)	321 (15.2)	59 (22.6)	0.001
Child characteristics (at birth)								
Gestational age at birth (weeks), mean (SD)	39.0 (1.0)	39.0 (1.0)	39.1 (1.0)	0.146	39.0 (1.0)	39.0 (1.0)	39.0 (1.0)	0.405
Boys, *n (%)*	1,888 (53.1)	1,594 (53.0)	294 (53.9)	0.631	1,320 (52.9)	1,165 (52.7)	155 (54.4)	0.522
Birth order >1, *n (%)*	1,137 (32.0)	976 (32.4)	161 (29.6)	0.155	756 (30.3)	681 (30.8)	75 (26.3)	0.098
Birth weight z-score, mean (SD)	−0.1 (0.8)	−0.1 (0.8)	0.0 (0.8)	0.03	0.0 (0.8)	0.0 (0.8)	0.1 (0.8)	0.129
Cesarean section, *n (%)*	1,043 (29.5)	907 (30.3)	136 (25.0)	0.002	776 (31.3)	710 (32.4)	66 (23.2)	<0.001
Child characteristics (at the time of neurodevelopment assessment)								
Age (months), mean (SD)	6.2 (0.5)	6.2 (0.4)	6.4 (0.6)	<0.001	12.3 (0.6)	12.3 (0.6)	12.6 (0.7)	<0.001
Duration of breast feeding (days), mean (SD)	169.6 (73.3)	167.9 (76.6)	180.7 (43.2)	<0.001	279.6 (104.2)	278.7 (104.0)	287.3 (106.0)	0.233
Body mass index z-score, mean (SD)	0.2 (1.0)	0.2 (1.0)	0.2 (1.0)	0.769	0.1 (0.9)	0.1 (0.9)	0.0 (0.9)	0.204
Head circumference z-score, mean (SD)	0.2 (0.9)	0.2 (0.9)	0.3 (0.9)	0.223	0.0 (0.9)	0.0 (1.0)	0.0 (0.9)	0.705

Percentages may not add up to 100% due to rounding.

P-values represent the statistical significance for the difference between 2015–2019 and 2020, tested by the t-test (for continuous variables) and χ^2 test (for categoricalvariables).

SD, standarddeviation.

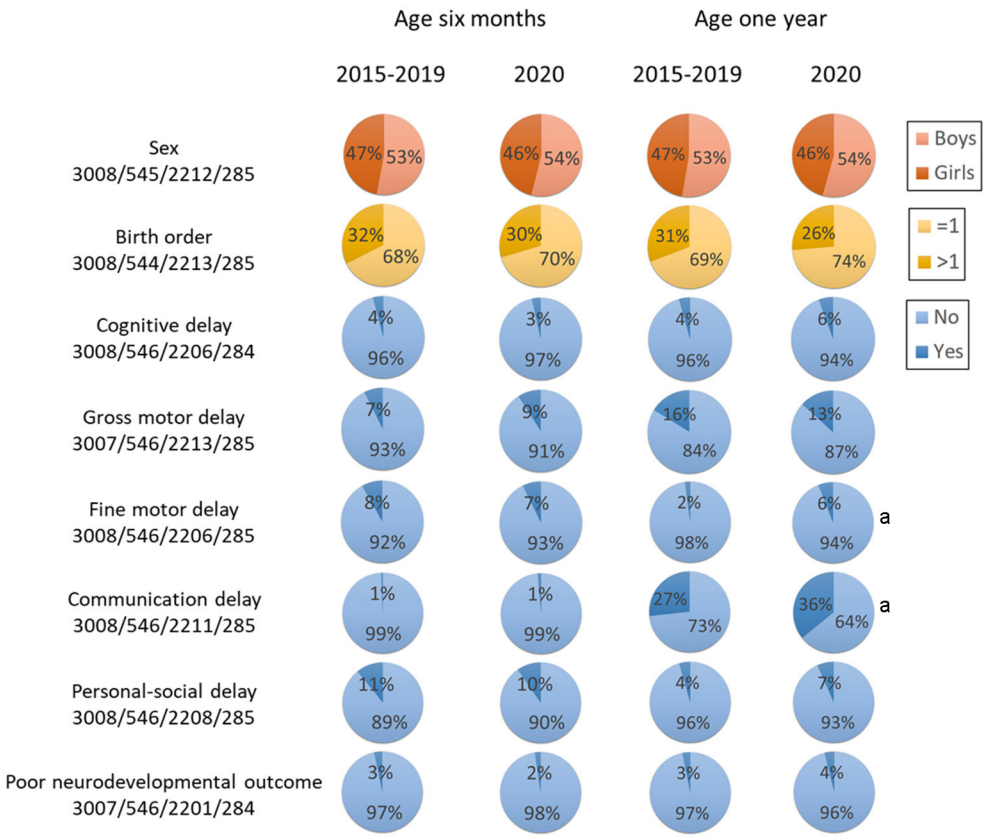

FIGURE 2 | Key characteristics by age and year. Poor neurodevelopmental outcome was defined as developmental delay in more than two domains. [a]Statistical significance compared with 2020 at the same age.

546 6-month-old and 285 1-year-old children who attended the neurodevelopment assessment between March 1 and May 15, 2020, were included as the exposed group, while 3,009 6-month-old and 2,214 1-year-old children during the same months from 2015 to 2019 were included as the non-exposed group.

Maternal and child characteristics are shown in **Table 1**, with data presented separately between the follow-ups at 6 months and 1 year, and between 2015–2019 and 2020. Maternal age at conception was around 30 years. As for child characteristics, gestational age at birth was around 39 weeks, and the proportion of boys was 52–54%. In 2020, the proportion of children born via cesarean section was lower than that in 201–2019. At the time of neurodevelopment assessment, the mean age of children included in the 6-month and 1-year follow-up was 6.24 and 12.31 months, respectively.

Figure 1 shows the age- and domain-specific trend of neurodevelopmental delay from 2015 to 2020 (see detailed data in **Supplementary Table 1**), whereas **Figure 2** shows the proportion of child sex, birth order, and neurodevelopmental delay in each domain by age in 2015–2019 and 2020, respectively. In 6-month-old children, the prevalence of neurodevelopmental delay assessed by the ASQ-3 fluctuated over the 6 years across all domains; and there were no differences in these proportions between 2015–2019 and 2020. At 1 year of age, while fluctuations in the prevalence of neurodevelopmental delay assessed by the GDS were also observed, the children in 2020 had a higher proportion of delay in the fine motor and the communication domains (both $P < 0.05$) than those in the previous years. Differences in the prevalence of neurodevelopmental delay were also observed between first-born and later-born children (**Figure 1**).

The association between the experience of COVID-19 and the risk of neurodevelopmental delay are shown in **Table 2**. No associations were observed in any domain at 6 months of age. Experiencing COVID-19 was associated with a higher risk of delay in the fine motor (adjusted OR [aOR]: 2.50, 95% CI: 1.25, 4.99) and communication (adjusted RR [aRR]: 1.13, 95% CI: 1.02, 1.25) domains at 1 year of age. **Table 3** shows the associations between the experience of COVID-19 and the risk of neurodevelopmental delay, stratified by birth order. At age 1 year, experiencing the COVID-19 pandemic in 2020 was associated with a higher risk of communication delay (aRR: 1.15, 95% CI: 1.13, 1.30) in first-born children, while this association was not observed in those who were later-born (aRR: 1.02, 95% CI: 0.84, 1.25). Notably, no associations with "poor neurodevelopmental outcome" were found in all analyses above.

TABLE 2 | Association between the experience of COVID-19 and child neurodevelopment at age 6 months and 1 year in all samples.

2020 vs. 2015–2019	Age 6 months		Age 1 year	
	Crude OR (95% CI)	Adjusted OR (95% CI)[a]	Crude OR or RR (95% CI)	Adjusted OR or RR (95% CI)[a]
Cognitive delay	0.85 (0.52, 1.38)	0.84 (0.46, 1.56)	1.31 (0.76, 2.26)	1.12 (0.58, 2.14)
Gross motor delay	1.26 (0.92, 1.74)	1.30 (0.89, 1.89)	0.82 (0.60, 1.12)[b]	0.91 (0.76, 1.09)[b]
Fine motor delay	0.89 (0.63, 1.26)	0.97 (0.65, 1.45)	2.85 (1.62, 5.03)*	2.50 (1.25, 4.99)*
Communication delay	1.93 (0.86, 4.34)	2.09 (0.87, 5.01)	1.34 (1.13, 1.59)[b]*	1.13 (1.02, 1.25)[b]*
Personal-social delay	0.88 (0.65, 1.20)	0.82 (0.56, 1.20)	1.52 (0.92, 2.53)	1.12 (0.56, 2.22)
Poor neurodevelopmental outcome[c]	0.72 (0.40, 1.30)	0.90 (0.46, 1.77)	1.23 (0.64, 2.35)	0.77 (0.30, 1.96)

*$P < 0.05$.
[a]*Adjusted for maternal age, education level, monthly income, delivery mode, child sex, birth order, birth weight z-score, breastfeeding duration, body mass index z-score, head circumference z-score, and maternal postpartum depressive symptoms.*
[b]*Estimated by log-binomial regression, shown as RR.*
[c]*Defined as developmental delay in more than two domains.*
CI, confidence interval; OR, odds ratio; RR, relative risk.

TABLE 3 | Association between the experience of COVID-19 and child neurodevelopment at age 6 months and 1 year, stratified by birth order.

2020 vs. 2015–2019	Age 6 months		Age 1 year	
	First-born	Later-born	First-born	Later-born
Cognitive delay—Adjusted OR (95% CI)[a]	0.90 (0.44, 1.85)	0.73 (0.22, 2.44)	1.09 (0.51, 2.34)	1.20 (0.32, 4.45)
Gross motor delay—Adjusted OR or RR (95% CI)[a]	1.12 (0.69, 1.81)	1.73 (0.92, 3.24)	0.98 (0.81, 1.18)[b]	0.69 (0.43, 1.13)[b]
Fine motor delay—Adjusted OR (95% CI)[a]	0.96 (0.59, 1.56)	1.05 (0.50, 2.21)	2.07 (0.88, 4.86)	3.47 (0.94, 12.90)
Communication delay—Adjusted OR or RR (95% CI)[a]	1.56 (0.51, 4.79)	–[c]	1.15 (1.03, 1.30)[b]*	1.02 (0.84, 1.25)[b]
Personal-social delay—Adjusted OR (95% CI)[a]	0.80 (0.51, 1.26)	0.83 (0.41, 1.66)	0.71 (0.28, 1.83)	2.74 (0.92, 8.13)
Poor neurodevelopment outcome[d]–Adjusted OR (95% CI)[a]	0.64 (0.25, 1.64)	1.64 (0.60, 4.44)	0.41 (0.10, 1.75)	1.87 (0.48, 7.21)

*$P < 0.05$.
[a]*Adjusted for maternal age, education level, monthly income, delivery mode, child sex, birth weight z-score, breastfeeding duration, body mass index z-score, head circumference z-score, and maternal postpartum depressive symptoms.*
[b]*Estimated by log-binomial regression, shown as RR.*
[c]*Omitted due to the small sample size.*
[d]*Defined as developmental delay in more than two domains.*
CI, confidence interval; OR, odds ratio; RR, relative risk.

DISCUSSION

To our knowledge, this is the first study to reveal the risk of neurodevelopmental delay in infants during the COVID-19 pandemic. In this comparison study with information on infant neurodevelopment from 2015 to 2020, we found that experiencing COVID-19 in 2020 was associated with a higher risk of neurodevelopmental delay in the fine motor and the communication domains in 1-year-old children, while no associations are observed for those at 6 months of age. The delay in the communication domain at age 1 year is mainly attributable to first-born children. Experiencing the pandemic was not associated with "poor neurodevelopmental outcome" at either age.

Although there are currently no other studies specifically investigating the influence of the COVID-19 pandemic and related prevention and control strategies on infant neurodevelopment, previous studies have shown that the COVID-19 pandemic and associated strategies (e.g., social isolation) may have a negative impact on the development and mental health of preschool-age and school-age children and adolescents. For example, a systematic review shows that children and adolescents are more likely to experience depression and anxiety during and after enforced social isolation (6). Similarly, other studies also reveal the reduction of life satisfaction and the exacerbation of psychiatric disorders in adolescents during the pandemic (5, 7). Our study adds new evidence to the literature regarding the association between the experience of the COVID-19 pandemic and neurodevelopment of infants. For the first time, our findings suggest that experiencing the COVID-19 pandemic may be associated with compromised neurodevelopment at 1 year of age, a critical window for the development of specific domain functions (40).

We observed that 1-year-old children experiencing the pandemic were at an increased risk of delay in the communication (language) and the fine motor domains than those not. Evidence shows that the protective factors of 1-year-old children who are in "at-risk" environments for language development include parental self-efficacy, relationship well-being, high social support, community participation, and daily

parent-child interaction (41). The COVID-19 pandemic might have negatively affected the mental health of the children's parents and reduced the contact with other family members, friends, and community members due to the containment strategies, thus potentially exerting a negative impact on children's language development. Fine motor skills are hand and finger skills such as picking up pellets with their thumb and forefinger. When staying indoors during the pandemic, some parents and caregivers (e.g., grandparents) might entertain their children with digital devices, thus increasing their screen time. Evidence (although from children of preschool age) has suggested that those who extensively use touch screen tablets might have poorer fine motor development than those who do not (42).

Our study also found that the association between the experience of COVID-19 and the risk of neurodevelopmental delay in specific domains among 1-year-olds only existed in first-born children, which seems inconsistent with previous evidence. It has been shown that first-born children tend to be more intelligent and receive more language interactions from their parents than later-born children (43, 44). There might be two reasons for this. First, during the pandemic, the children stayed at home all day with their elder brothers or sisters, and the extensive interactions with their elder siblings might alleviate the potentially negative impact of social distancing and home confinement measures. Second, as the pandemic has universally caused anxiety and depression in the general population (45), new parents may be less experienced in coping with these emotions, and the infants born to them might be more vulnerable to developmental issues. However, these findings still need to be replicated and confirmed by other studies in the future.

The different findings between 6-month-olds and 1-year-olds in our study are also noteworthy, which might be attributed to the differences in the sensitive periods for neurodevelopment and the assessment tools used in the two groups. For the children included in the present study, most of them experienced the COVID-19 pandemic at age 4–6 or 10–12 months. Evidence has shown that children reared institutionally at 4–6 months of age did not have a significantly increased risk of adverse developmental outcomes across most domains compared with their non-institutionalized counterparts, (46) suggesting that this period might be less sensitive to negative impacts, which is in line with our findings for 6-month-olds. On the other hand, infants start to discriminate native and non-native phonemes at age 6–12 months (47), rendering this period a likely sensitive time window for language/communication development, which is also supported by our findings for 1-year-olds. Although there is a lack of evidence on the sensitive periods for fine motor development, especially within infancy, a study of preschool-aged children has found some sensitive periods for fine motor development during 2.8–6.5 years of age (48). Our findings also suggest the possible existence of sensitive periods for fine motor development within infancy, which is worth further exploration. In addition, the different assessment scales used in these two groups could be an alternate explanation. Unlike the GDS, which is a diagnostic tool and often used as a reference in validation studies, the ASQ is a concise screening tool suitable for use in large-scale epidemiologic studies. As the GDS contains more items and has a more detailed assessment and scoring process than the ASQ, we cannot rule out the possibility that the ASQ might have failed to identify any subtle differences in the development of 6-month-olds. Therefore, the results of these two groups might not be directly comparable with each other and should be interpreted independently.

The present study has several strengths. Firstly, this is the first study to examine the relationship between the experience of the COVID-19 pandemic and infant neurodevelopment. Secondly, information on the variables used in this study was prospectively collected, and the analyses were adjusted for a range of potential confounders. Thirdly, children's neurodevelopment at 6 months and 1 year old was examined by trained clinical staff.

Our study also has some limitations. Firstly, we could not obtain the information on the degree to which the children's families complied with the social distancing and home confinement strategies. It is likely that not all families kept social distancing and stayed at home during the pandemic, and those who less cared about the strategies seemed more likely to attend the 6-month or 1-year follow-ups in the hospital. Secondly, although we stratified the children by birth order, the number of family members living together with the children is unknown, which might also influence child neurodevelopment. Thirdly, due to the different assessment tools used in the 6-months and 1-year children, the results might not be directly comparable between these two age groups. Fourthly, we could not rule out the possible bias caused by the fluctuation of outcome prevalence over time. To alleviate this issue, we combined the data from 2015 to 2019 in the analysis to obtain a relatively stable outcome prevalence for the reference group. In addition, this study only included neurodevelopment within infancy, and longer follow-ups are thus needed to explore the potential influence of this experience on long-term developmental outcomes of children. Moreover, this study was based on the Chinese population, which limits the generalizability of our findings. Replication by future studies from other regions and populations is needed. Lastly, residue confounding might exist due to the observational nature of the present study.

Several implications can be drawn from this study. First, our findings suggest that the experience of the COVID-19 pandemic might potentially have a negative impact on child neurodevelopment in specific domains at specific ages, which raise concerns about the development of young children under the COVID-19 pandemic. Parents need to pay more attention to their children's development and adjust their rearing patterns at this special time (44). Second, given the absence of an association with "poor neurodevelopmental outcome," this potential negative impact seemed to affect only a limited number of domains and have minor influences on the overall developmental outcome of the children. Third, for families with two or more children, the key to minimize the impact of the pandemic on the children's development might be to increase the interaction of children with their siblings and other family members. Fourth, for child healthcare practitioners, it is necessary to consider using the

internet, such as social media and other communication software, to practice health education and provide online assessment and intervention instructions for parents during the pandemic (49, 50). Moreover, studies are needed to further explore the impact of COVID-19 on child health and its underlying mechanisms. Evidence has suggested that pregnant women tend to report adverse lifestyle changes during the COVID-19 pandemic (e.g., having poorer diet quality and less sleep, and being less physically active); (51) some of these changes might, in turn, influence offspring's physical and mental health, such as neurodevelopment (52, 53). Thus, future research is warranted to investigate the potential influence of COVID-19 on offspring health mediated by the changes in women's behaviors and lifestyles during pregnancy.

In conclusion, this study found an association between the experience of COVID-19 and a higher risk of neurodevelopmental delay in the fine motor and the communication domains in 1-year-old children; the association observed in the communication domain only existed in first-born children. No associations were found in 6-month-old children. These findings underline the need to concern about the neurodevelopment of infants who are experiencing the COVID-19 pandemic and call for more training in specific domains at home, which requires the joint efforts of both parents and child healthcare practitioners.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Institutional Ethics Committee of Guangzhou Women and Children's Medical Center. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

HX and XQ conceptualized and designed the study, supervised its implementation, and reviewed and revised the manuscript. PH and FZ carried out data analysis, drafted the initial manuscript, and reviewed and revised the manuscript. YG, SY, SL, JL, ST, ML, and SS were involved in study design, questionnaire development, data collection and management, follow-up of participants, and critically reviewed the manuscript for important intellectual content. AG interpreted the data and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.662165/full#supplementary-material

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BRIEF RESEARCH REPORT
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"A Piece of Sanity in the Midst of Insane Times": *Girls on the Run* Programming to Promote Physical Activity and Psychosocial Well-Being During the COVID-19 Pandemic

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Afterschool programs have the potential to promote social, emotional, and physical health outcomes among youth participants. The positive youth development (PYD) framework argues that acquiring desirable attitudes and behaviors occurs when skill-building opportunities are explicitly provided within a safe and supportive climate guided by caring, competent, and compassionate instructors. *Girls on the Run* (GOTR) is a PYD program that uses running, motor skills, and other physical activities as a platform for promoting positive psychosocial outcomes and life skills learning among elementary- and middle school-aged girls. The onset of the COVID-19 pandemic challenged GOTR to modify lessons, coach training, and program delivery (in-person, virtual, or hybrid) to accommodate public health guidelines. The purpose of this study was to assess caregivers' and coaches' perceptions of program effectiveness in light of these changes. Following the Fall 2020 season, caregivers (n = 1,617) and coaches (n = 991) from 1,077 teams and 39 councils completed an online survey about program experiences. Both stakeholder groups positively rated program impact regardless of delivery mode, although in-person mode was rated higher for satisfaction with the end-of-season event. Thematic analysis of open-ended responses revealed that caregivers and coaches identified increased physical activity opportunities and life skills learning as well as improved social, psychological, and emotional development as a result of participating. Both stakeholders noted GOTR provided a sense of normalcy during this time of great need. Findings using mixed methods provide evidence of program effectiveness and recommendations for youth programming during challenging times.

Keywords: positive youth development, out-of-school-time, youth sport, social-emotional learning, holistic health

INTRODUCTION

Girls on the Run (www.girlsontherun.org) is a physical activity-based positive youth development (PA-PYD) program using running, motor skills, and physical activities as a platform for promoting psychosocial development and life skills among girls 8–11 (grades 3–5) and 12–14 years (grades 6–8). The program typically serves 200,000 girls annually and engages 50,000 coaches (98% female). The intentional curriculum and systematic coach training are aligned with best practices for PYD programs, including opportunities for skill building, a safe physical and psychological space, appropriate structure, supportive relationships, and feelings of belonging (1, 2).

The program adopts Lerner's Five *Cs* framework to guide lessons comprising the life skills curriculum (3). Lessons are designed to help girls develop social, emotional, and physical *competence*, feel *confident* in who they are, create positive *connections* with peers and adults, develop strength of *character*, and respond to others and self with *care* and compassion. A sixth C reflects *contribution* to the greater good through implementing a community service project. The curriculum for 3rd−5th grade girls focuses on three themes: identity (self-care and self-awareness), connectedness (selecting and maintaining healthy relationships), and empowerment (celebrating and sharing one's strengths), while the 6th−8th grade curriculum focuses on lessons related to self, team, and community. Sessions also prepare girls to complete the culminating 5 K, by setting goals, regulating progress, and participating in a practice 5 K to build confidence. To attain program goals, girls and coaches meet twice a week for 75–90 min over a 10-week season. Coaches are trained to deliver the curriculum with fidelity, along with an emphasis on building relationships, creating a positive, inclusive environment, and emphasizing a mastery climate. More information about GOTR is available in other sources [e.g., (4–6)].

Evidence of program effectiveness shows GOTR's impact on physical activity, life skills, and holistic health [e.g., (7–10)]. Pre- to post-season improvements emerged for activity levels, self-esteem, physical competence, and peer support; these were retained 3 months after season's end. Life skills transfer for managing emotions, helping others, resolving conflicts, and decision-making favorably compared to girls in organized sport and school physical education. Qualitative data from girls, caregivers, coaches, and school personnel indicated that girls improved in social and emotional behaviors and physical activity motivation as a result of participating in GOTR.

The onset of the COVID-19 pandemic challenged GOTR to modify program delivery to accommodate public health guidelines, while continuing to promote PYD in a time of great need. The curriculum was shortened from 20 to 16 lessons and delivery options included in-person, virtual, or hybrid. Health and safety policies were adopted utilizing CDC guidance for all modes. When in person, coaches delivered pre-COVID lessons with modifications for physical distancing (e.g., "air" high fives, shadow tag) and the use of new journals outlined in a curriculum addendum. Girls also used the journals in the virtual space. If a team was 100% virtual or needed to transition to the virtual space (i.e., hybrid), coaches used the newly developed Virtual Lesson Curriculum, which contained lessons that mirrored the in-person learning objectives. Virtual lessons were shortened to 45–60 min plus a 20–30-min independent workout (modified from 75–90 min in-person lessons), and a variety of physical activities were provided to be inclusive and allow for space constraints (modified from in-person workouts that primarily included running and other locomotor skills). The workout typically completed in person was transitioned to a "separate but together workout" that girls started together at the end of the lesson and continued on their own. Coach training, typically delivered in-person (4.5 h) and online (1 h), was moved to completely online. Three training modules were added: impact of COVID-19, coaching virtually, and coaching for social inclusion. The end-of-season 5 K, typically a large community celebration, became a "K Your Way" event.

Consistent with GOTR's commitment to ongoing evaluation for improving curricula and program delivery, the organization developed an online survey to seek caregivers' and coaches' perceptions of program effectiveness in light of COVID-19 protocol changes. Based on utilization-focused evaluation, Patton (11) accentuates bridging empirical research and practical implications of evaluation findings. He suggests that evaluations provide answers to three questions: (1) *What* information emerges about attitudes, skills, and behaviors? (2) *So What* do findings imply about program effectiveness? (3) *Now What* recommendations can be made for making program improvements? The purpose of this study was to answer these questions based on stakeholders' perceptions of COVID-19 safety protocol changes to program delivery.

METHOD

Following the Fall 2020 season, all GOTR councils (∼200) were invited to evaluate the curricular and delivery modifications due to COVID-19 restrictions. Thirty-nine councils elected to participate, consisting of 1,077 teams in all regions of the U.S. GOTR national headquarters distributed an online survey to all caregivers and coaches within the 39 councils.

Caregivers

A total of 1,617 caregivers completed the survey. They reported their girls' program delivery mode as virtual (23.3%), in-person (54.3%), and hybrid (22.4%). For girls' race/ethnicity, 73% were white/Caucasian, 7% Black/African American, 7% multiracial, 6% Latina, 3% Asian, 0.4% American Indian/Alaskan Native, 0.3% Native Hawaiian/Pacific Islander, and 1% Other (∼2% did not say). Most girls (91%) were in grades 3–5 and 9% were in grades 6–8.

Coaches

A total of 991 coaches completed the survey. They delivered the program as virtual (32.1%), in-person (47.3%), and hybrid (20.6%). The majority were white/Caucasian (84%), with 4% Black/African American, 3% Asian, 3% Latina, 3% multiracial, 0.3% American Indian/Alaskan Native, 0.1% Native Hawaiian/Pacific Islander, and 1% Other (∼2% did not say).

TABLE 1 | ANOVAs for caregiver items by delivery mode: *F*- and *p*-values, means, standard deviations, and effect sizes.

Survey question:	*F*-value (*p*-value)	*M* (*SD*)			Cohen's *d*	
		Virtual	In-person	Hybrid	Virtual vs. in-person	Virtual vs. Hybrid
GOTR has been a valuable experience for my girl.	*19.73 ($p < 0.001$)	4.48 (0.77)	4.73 (0.61)	4.68 (0.63)	0.33	0.26
GOTR helped my girl gain skills that are helping her handle the stress associated with the pandemic.	4.80 ($p = 0.008$)	4.24 (0.83)	4.38 (0.73)	4.37 (0.77)	—	—
GOTR has led to at least one conversation with my girl about an important topic.	0.78 ($p = 0.46$)	4.23 (0.89)	4.27 (0.83)	4.31 (0.81)	—	—
Because of participating in GOTR, my child is more confident.	*9.54 ($p < 0.001$)	4.07 (0.87)	4.28 (0.75)	4.25 (0.77)	0.24	0.21
The COVID-19 precautions in place gave me confidence that GOTR was striving to create a safe experience for my girl.	1.15 ($p = 0.28$)	—	4.56 (0.85)	4.51 (0.81)	—	—
How satisfied were you with the end-of-season event?	*34.09 ($p < 0.001$)	4.02 (1.11)	4.54 (0.97)	4.43 (1.02)	0.47	0.37
Before vs. after GOTR — My girl feels lonely.	4.65 ($p = 0.01$)	−0.49 (0.99)	−0.69 (1.05)	−0.63 (1.06)	—	—
Before vs. after GOTR — I would describe my girl as confident.	0.22 ($p = 0.80$)	0.51 (0.84)	0.54 (0.77)	0.54 (0.74)	—	—
Before vs. after GOTR — My girl is physically active.	1.56 ($p = 0.21$)	0.66 (0.93)	0.76 (0.94)	0.70 (1.01)	—	—

*All responses were on a 1–5 scale. A p-value of <0.006 was deemed a significant effect, based on a Bonferroni adjustment (0.05/9 items). *Denotes significant effect. Cohen's d was calculated for statistically significant differences. No statistically significant differences emerged for In-Person vs. Hybrid delivery modes. Change score indicates "after minus before", thus caregivers in all three delivery modes reported their girls decreased in loneliness and increased in confidence and physical activity.*

Most coaches were between 25–44 years old (61%); 39% were first-timers with GOTR, while 61% coached for ≥2 years.

Survey Questions

For caregivers, 5 statements probed level of agreement on the GOTR experience (**Table 1**), ranging from strongly disagree (1) to strongly agree (5). Another question sought degree of satisfaction with the end-of-season event, ranging from completely dissatisfied (1) to completely satisfied (5). They also rated "how true" a statement was ("my girl feels lonely", "my girl is confident", "my girl is physically active") before and after participation in GOTR, ranging from not true at all (1) to really true (5). Coaches responded to 8 statements probing level of agreement about their GOTR experience and 3 questions about how satisfied they were with the COVID-19 safety protocols, end-of-season event, and communication from GOTR (**Table 2**).

One open ended question for each stakeholder was selected for qualitative analysis based on relevance to the COVID-19 protocol changes. For caregivers, "Share one way that your girl has been positively impacted by her *Girls on the Run* experience, such as something she learned, a favorite moment or activity, or a lasting takeaway." For coaches, "This is a challenging time for many girls. What do you think was the greatest need met through the program during this time?"

Data Analysis

Quantitative responses were analyzed using analysis of variance to determine delivery mode differences. We applied a Bonferroni adjustment to avoid Type 1 errors (12). For caregivers, statistical significance was determined using $p < 0.006$ (0.05/9 items) and for coaches using $p < 0.005$ (0.05/11 items). Student-Newman-Keuls *post-hoc* tests were used in the event of statistically significant differences. Effect size (ES) was calculated for statistically significant differences using Cohen's d (13): $d \geq 0.20$ = small, ≥0.50 = medium, ≥0.80 = large.

An inductive content analysis was adopted for the qualitative responses (14). One researcher initially coded data units (words, phrases, sentences) and lower-order themes for half the sample of caregivers ($n = 780$) and coaches ($n = 458$) due to early saturation of responses. A second researcher randomly selected 100 responses for each stakeholder and independently coded data units and lower-order themes. The researchers then met to discuss convergence and divergence of findings and came to consensus. Together they derived a set of higher-order themes that emerged from the lower-order themes and data units (14).

RESULTS

Caregivers: Quantitative Responses

Responses (**Table 1**) fell between agree and strongly agree regardless of delivery mode (virtual, in-person, hybrid). Caregivers favorably viewed the COVID-19 safety precautions in the in-person and hybrid modes. Analysis revealed no differences for: (a) gained skills for handling stress, (b) participating led to at least one conversation between caregiver and girl about an important topic and (c) COVID-19 precautions gave confidence that GOTR was striving to create

TABLE 2 | ANOVAs for coach items by delivery mode: *F*- and *p*-values, means, standard deviations, and effect sizes.

Survey question:	*F*-value (*p*-value)	*M* (*SD*)			Cohens *d*		
		Virtual	In-person	Hybrid	Virtual vs. in-person	Virtual vs. hybrid	In-person vs. hybrid
Coaching Girls on the Run has been a valuable experience for me.	*5.95 ($p = 0.003$)	4.77 (0.45)	4.77 (0.47)	4.63 (0.64)	–	−0.32	−0.22
I formed positive relationships with the girls on my team.	*8.88 ($p < 0.001$)	4.55 (0.60)	4.73 (0.51)	4.66 (0.55)	0.29	0.18	–
Girls on my team developed positive relationships with their teammates.	*24.77 ($p < 0.001$)	4.31 (0.75)	4.65 (0.55)	4.55 (0.58)	0.44	0.32	–
As a Girls on the Run coach, I felt like I was making a difference in girls' lives.	2.40 ($p = 0.09$)	4.48 (0.61)	4.57 (0.62)	4.50 (0.60)	–	–	–
Because of participating in Girls on the Run, girls on my team are more confident.	4.76 ($p = 0.009$)	4.39 (0.63)	4.53 (0.63)	4.44 (0.60)	–	–	–
I received sufficient training to effectively implement the program.	1.34 ($p = 0.26$)	4.42 (0.66)	4.48 (0.67)	4.41 (0.71)	–	–	–
Coach support was available to me throughout the season.	1.21 ($p = 0.30$)	4.65 (0.57)	4.58 (0.66)	4.59 (0.61)	–	–	–
I had the support I needed to coach during COVID times.	0.16 ($p = 0.86$)	4.54 (0.63)	4.57 (0.64)	4.55 (0.65)	–	–	–
How satisfied were you with the COVID-19 related safety protocols implemented this season?	0.01 ($p = 0.92$)	–	4.50 (0.99)	4.51 (0.99)	–	–	–
How satisfied were you with the end-of-season event?	*34.67 ($p < 0.001$)	3.85 (1.09)	4.48 (0.95)	4.33 (1.00)	0.58	0.44	–
How satisfied were you with the communication from Girls on the Run?	0.26 ($p = 0.77$)	4.62 (0.84)	4.66 (0.81)	4.65 (0.79)	–	–	–

*All responses were on a 1–5 scale. A p-value of <0.005 was deemed a significant effect, based on a Bonferroni adjustment (0.05/11 items). *Denotes significant effect. Cohen's d was calculated for statistically significant differences.*

a safe experience for girls. Two items showed a difference favoring in-person vs. virtual and hybrid vs. virtual—valuable experience and my girl is more confident. ES's were small. No statistical differences emerged for in-person vs. hybrid delivery modes.

Caregivers reported the location of their end-of-season event as in-person at site (72.3%), virtual (22.0%) or other (5.7%). Satisfaction ratings with the event fell between somewhat and completely satisfied for all delivery modes, but caregivers of girls who participated in virtual sessions scored significantly lower than girls who experienced in-person or hybrid lessons. ES's were small.

For the before and after questions —"my girl felt/feels lonely", "I would describe my girl as confident", and "my girl was/is physically active"—scores improved for all three delivery modes. Caregivers reported girls as less lonely, more confident, and more physically active. No differences in change scores emerged by delivery mode.

Coaches: Quantitative Responses

Responses (**Table 2**) fell between agree and strongly agree regardless of program delivery. Coaches reported positive experiences across the board, including high ratings for "coach support was available to me throughout the season" and "I had the support I needed during COVID times." Coaches favorably viewed COVID-19 safety protocols for in-person and hybrid modes. No differences emerged for: (a) received sufficient training to effectively implement the program (b) as a GOTR coach, I felt like I was making a difference in girls' lives, and (c) because of participating in Girls on the Run, girls on my team are more confident.

In-person delivery received more favorable scores than virtual delivery for: I formed positive relationships with girls on my team and girls developed positive relationships with teammates; these items were also higher for hybrid vs. virtual. All ES's were small. When asked if coaching GOTR has been a valuable experience, coaches in the hybrid mode scored significantly lower than virtual and in-person modes, but ES's were small.

Coaches reported location of the end-of-season event as in-person at site (62.5%), virtual (28.7%) or other (8.9%). Satisfaction ratings with the event were significantly higher for coaches who delivered the program in-person or hybrid than for virtual mode. ES's were small (virtual vs. hybrid) and medium (virtual vs. in-person). No differences emerged between delivery modes for satisfaction with safety protocols and support and communication from GOTR.

Caregivers: Qualitative Themes

Coding responses to, "Share one way that your girl has been positively impacted by her GOTR experiences …" resulted in 9

higher-order themes derived from 15 lower-order themes and hundreds of data units. **Table 3** depicts the thematic analysis.

Improved Physical Activity Motivation and Behavior was evident in data units revealing opportunities for being physically active with teammates and looking forward to running and training for the 5 K. As one parent said, "My daughter has grown to love running and wants to run with me now. She sees herself as a runner and this is a positive identity that she will carry with her into the future." Another parent shared, "My daughter did not like to do any physical activity prior to this program. After GOTR, she would come home in such a positive mood and feeling better about herself. Now she is pushing me to incorporate exercise into our lives and strives to be a healthy person."

Social Development was characterized by opportunities to develop and strengthen friendships, socially interact with peers, and experience group belongingness—various ways that allowed girls to share common bonds with others their age. One parent offered, "This was a wonderful way for Sadie[1] to get reconnected with kids her age and have some meaningful experiences in the midst of this COVID chaos. Thank you for providing a safe and supportive way for her to be with other kids and continue working on her running skills." This parent gave a more vivid example, "My daughter became motivated and dedicated to completing her own physical fitness routine because of the positive energy and camaraderie generated by her GOTR coaches and team. She felt she was part of something important, a little bit more connected to others and appreciated as a person."

Psychological Growth was defined by themes of achieving goals and gaining confidence. Caregivers attested to girls setting goals and developing strategies to successfully complete them (e.g., 5 K). Others highlighted how confidence was enhanced through activities and lessons in GOTR. One parent shared, "My daughter was really struggling and feeling alone during COVID. She lost her motivation and happy spirit … After just one practice she was happy again. She was eager to set goals and achieve them. As she achieved goals her confidence grew. This program was even more important this year!"

Emotional Growth entailed themes of being able to express feelings, adopting a positive outlook, and feeling proud of accomplishments. Responses alluded to becoming more open with communicating, engaging in positive talk, and feeling a sense of pride in completing the 5 K. A parent shared, "She was really struggling with COVID and not being able to be with her friends … when she started GOTR back up she was excited, she looked forward to each session, it brought her back to life and her outgoing self again." Another offered, "GOTR gave her peers to interact with … she was able to share her thoughts on the lesson without hesitation. GOTR has always been a positive, uplifting experience where she feels accepted."

Life Skills Development was prominent, characterized by learning life lessons and helping others. Caregivers confirmed that girls acquired specific "tools" (Take a Breather) and learned important skills (e.g., choosing good friends) that transferred to

TABLE 3 | Caregiver responses: lower-order themes and data units within each higher-order theme.

Lower-order theme:	Data units:
Higher-order theme: improved physical activity motivation and behavior	
Physical activity opportunities	Learning to be more physically active
	Becoming more active
	Discovered she loves running as an activity
	Outdoor exercise
	Looked forward to running
	Running has gotten better
	Loves running with her friends
	Found she is good at running
	More active in the outside than before
	Understands how important daily physical activity is to her well-being
	Energetic from the workout
	Training for, committing to, and completing a 5 k
	Wants to run track now
	Excited about exercise
	Understands the value of being active
	She has a new love for running
	Enjoys the movement activities during each session
	The exercise helped give her balance with the virtual school day
	She's focusing on fitness
	Being able to run longer distances
	Learning to be active by running
	Helped her gain physical strength as she recovered from an injury
	Lots of fun exercise
	Love to run
	Now enjoys exercising
	Learned that she really enjoys running and that she can do it
	My daughter values physical activity as a way to release stress
	Getting more physical activity
	She has better endurance
Higherorder theme: social development	
Building friendships	Making new friends (numerous entries)
	Formed long-lasting friendships
	Connected with friends
	Seeing friends virtually or in person
	Time spent with friends
	Brought her closer to girls she otherwise would not have been able to get to know
	Made lifelong friends that she calls her sisters
Opportunity for social interactions	Interacting with girls
	More outgoing
	Came out of shell
	Conversations with teammates
	Helped her open up more
	Positive interactions with her peers
Feeling a part of the group/team	Team spirit
	Sense of community
	Feeling of belonging
	Group activities
	Being part of a team and lifting each other up
	Made her feel like a welcome part of a group
	Built a strong camaraderie with the other girls
	Loved how everyone cheered and uplifted each other
	A fun sense of belonging
	Team building
	Bonding with the other girls

(Continued)

[1] All names are pseudonyms.

TABLE 3 | Continued

Lower-order theme:	Data units:
Higher-order theme: psychological growth	
Achieving Goals	Striving toward a goal such as 5 k
	Setting goal for 5 k
	Meeting/exceeding goal for 5 k
	Pushed self to achieve running goals
	Got better at accomplishing goals
	Felt a strong sense of achievement after running the 5 k
	She was able to complete it (5k) without stopping and felt successful in her efforts
	Able to prove to herself that she could do more than she initially thought possible
	Learned that she can push herself to accomplish big goals
Gaining confidence	Willingness to try new things
	More confident about running
	Gained confidence
	Now confident enough to volunteer to speak in group Zoom meetings
	She has the confidence that she can tackle any challenges
	Confidence in running the 5 k
	Confidence demonstrated by her growing comfort in engaging in new activities
	Confidence with being a leader
	She doesn't doubt herself so much anymore on the first try
	Now has the mindset that girls can be strong and do anything!
	More confident with exercising
	She knows she can do hard things
Higher-order theme: emotional growth	
Being able to express feelings	Talk about feelings
	More open
	More outspoken
	Learned how to better communicate her feelings
	More willing to share and speak publicly
	Learned to make her voice heard
	Voices her opinion more
	Talking about her feelings when she gets frustrated
	Using positive words to speak with those who upset her, or she disagrees with
	She is more articulate about her emotions
	More open to talk to me
	Expressing her feelings
	Talk about emotions more freely
	She has emotionally matured since doing GOTR
Adopting a positive outlook	Positive thinking
	Being optimistic
	Using positive self-talk
	Positive attitude
	Motivated
	Using positive language about herself
	Learning about positivity and being uplifting
	A lot of positive encouragement
	Positive self-statements/positive thinking skills
	Learned how to think more positively
Feeling proud of accomplishments	Sense of pride for finishing 5 k
	Proud of overcome a hard physical task (5 k)
	Proud to have run as far as she did
	Proud of herself to finish her 5 k her way
	Proud she completed the 5 k without quitting
	Pride in running longer distances

(Continued)

TABLE 3 | Continued

Lower-order theme:	Data units:
Higher-order theme: life skills development	
Learning life lessons	Star Power (learned how to activate her Star Power)
	Strategies to cope with stress
	Choosing good friends
	Learned to enjoy the success of others rather than only celebrating her own achievements
	Used some of the lessons to work through problems with her little sister
	Learning about making healthy choices
	Understanding of empathy
	Tries to brainstorm ways to positively problem solve when a problem arises
	Coping skills for stressful situations
	Looking out for your friends
	Learned to be more of a leader
	Learned more about her feelings and some things to do to make her feel better when she's anxious
	Gave her a chance to develop a positive body image
	She has a better understanding of true friendships and how to cope with life's challenges
	Emphasis on heathy lifestyle both physically and mentally
	Learned dedication, positive thinking and improved self-esteem
	Toolbox for navigating emotions, peer relationships, and social dynamics
	Helped my daughter socially, emotionally, and physically
	She's aware of her health choices and mental break options in keeping herself happy
	Gained quite a bit of empathy
	Improving social skills
	Learned how to communicate more clearly
	She learned she is able to push herself beyond what she was able to do before.
	Learned strategies for helping her stay calm
Helping others	Learned about giving back
	Community service project
	Sense of civic engagement
	Donating to charities
	Encouraging teammates
	Providing words of encouragement to the other girls
	Thinking about her communities
	Helping her community
	Community project helped her feel empathy for others
	Be supportive for each other
	Ran extra laps with her friends in order to support them
Higher-order theme: positive coaching influence	
Positive coaching influence	Trusted coaches
	Coaches were positive role models
	Loved her coach
	Encouragement she gets from the coaches
	Interacting with adults outside the family
	Having coaches who were engaged and interested in listening
	Enjoyed the positive feedback and encouragement from her leaders
	Felt safe in speaking her opinion and that's cause the leaders fostered that environment
Higher-order theme: closer family connections	
Closer family connections	Stronger connections with parents and siblings
	Running together

(Continued)

TABLE 3 | Continued

Lower-order theme:	Data units:
	Discuss lessons with mother
	Going on a weekly jog as a family
	Running with her mom at the 5 k
	More positive and patient with her family
	We have been taking daily walks as a family to remind us all to be more active
	This has been something we could do together
	She had some hilarious conversations that gave the entire family a laugh—something we all very much need right now!
	She came home one day from GOTR and we had a conversation about how girls apologize too much, and I LOVED this conversation!
Higher-order theme: having fun	
Having fun	Enjoy the program
	Enjoy running
	Enjoy the girls
	Being silly
	Having fun in the program
Higher-order theme: sense of normalcy during the pandemic	
Sense of normalcy during the pandemic	Gave her something to look forward to each week
	Getting outside
	Being with girls aside from virtual school
	Allowed for safe and positive interaction with schoolmates
	Spending time with a small group of girls in a comfortable and honest setting
	Made her feel like she was living some normal moments.
	Grateful to have a covid-safe option when so many activities are canceled
	She appreciated the time to do something NORMAL in this not-normal year
	Having a social and active outlet during pandemic
	GOTR experience helped her feel much more connected to the school community at a time of stress and loneliness

many areas of girls' lives. A parent shared, "The lessons have been so helpful for Pria. We have gone back to lessons again and again and generalized for everyday life. Positive self-talk and Take a Breather helped us get through things like the flu shot and a medical procedure that was pretty scary. As a child with anxiety … having those tools in her toolkit helped us more than I can express in words." Helping Others was a theme reinforcing lessons that emphasize standing up for others (being a "Stand-Byer") and giving back to community and society. Developing empathy and a sense of civic engagement is accentuated in the curriculum through completion of a community service project.

Two higher-order themes revolved around meaningful adult relationships, Positive Coaching Influence and Closer Family Connections. Caregivers were uniformly praiseworthy of their girls' coaches as positive role models, sources of encouragement, and fostering a safe and inclusive climate. In addition, several caregivers commented on how girls' involvement in GOTR fostered opportunities for being physically active as a family and having conversations related to lesson themes. Having Fun was a theme that reflected the sheer enjoyment of running, being with peers, and experiencing the overall program.

A Sense of Normalcy during the Pandemic emerged as directly relevant to the COVID-19 pandemic. Caregivers praised the value of the program in light of virtual school and other social activities being canceled. One parent summarized concisely, "She appreciated the time to do something NORMAL in this not-normal year." Another shared, "My daughter was new to her school and with it being virtual, she hadn't met anyone. Her GOTR experience helped her feel much more connected to the school community at a time of stress and loneliness."

Coaches: Qualitative Themes

Coding responses to, "… What do you think was the greatest need met through the program during this time" resulted in 7 higher-order themes derived from 9 lower-order themes and hundreds of data units. **Table 4** depicts the thematic analysis.

Some themes were similar to those of caregivers, revolving around opportunities to socialize with peers, be physically active, build confidence, learn life lessons, be surrounded by a positive social environment, and feel a sense of normalcy. One coach nicely summarized how GOTR met girls' needs during this challenging time: "Giving girls the opportunity to get out of the house and develop strong habits/practices in exercise, mental health, confidence, and relationships."

Numerous responses exemplified the theme, Increased Physical Activity, including opportunities to be physically active by getting outside, participating in sports and activities with friends, and as one coach implored, "Encouraged them to get up and MOVE!" Another shared, "Many parents told us that before GOTR, their girls were not getting any physical activity. Not only were they active during the lesson, but it continued at home too." As a PA-PYD program, GOTR is unique in emphasizing physical activity as a healthy behavior through opportunities to enjoyably experience running, motor skills, and movement activities that are continued outside of the structured program.

Social Development entailed themes of socializing with peers and feeling part of a group. Coaches highlighted meaningful interactions and relationships as a crucial need that was achieved through activities promoting teamwork, unity, connectedness, and companionship. One coach shared, "The program provided the girls an opportunity to meet and interact with other girls and school staff (coaches). This gave the girls a much-needed opportunity to socialize with peers/adults during the difficult time caused by COVID (school closures, social distancing)." Another added, "I think social interaction was the greatest need. Girls had a platform to share in their joys, excitement, triumphs and hardships. My girls made valuable connections and even exchanged numbers to keep in touch with one another."

Psychological Growth included lower-order themes of coping with stress and building confidence. Coaches elaborated on how GOTR met these needs, "It gave the girls a sense of calm in all this chaos", "Having lessons on emotions bridges gaps with how they are feeling and how they can express it", and "They just needed someone besides people in their immediate households to talk with and to explore the world around them with different people so that they weren't stuck stressing about school. They got the opportunity to put some stress aside to have fun and to become a stronger and more confident girl."

TABLE 4 | Coach responses: lower-order themes and data units within each higher-order theme.

Lower-order theme:	Data units:
Higher order theme: increased physical activity	
Opportunities to be physically active	Physical activity Not only were they active during the lesson, but it continued at home too Able to get outside and exercise More active Being able to do the 5 k Movement Participate in an outdoor activity with friends Exercise and moving their bodies Time to move Ability to be outside exercising with other girls Opportunity to get outside and move Got to be active which they don't do during online learning Opportunity to be active with others Getting exercise Giving them a lot of moving time Keeping girls active Opportunity to enjoy their love for running following the safety guidelines Able to participate in a sport/activity Exercise outdoors Encouraged them to get up and MOVE! Getting outdoors for physical activity A chance to be active Opportunity to have an outlet for activity
Higher-order theme: social development	
Socializing with peers	Meaningful social interaction Connecting with teammates Social and peer interaction Need for social and emotional interaction A place to be sociable and silly Opportunity to connect with peers in a fun and safe way Time to socialize with peers Chance to engage with others in a positive manner Building relationships and being able to spend time with peers Created socialization opportunities Fellowship with others Interactions with peers See their friends Make new friends Forming relationships Forming better friendships and getting along well Allowing girls to socialize Connecting through positive experiences
Feeling part of a group/team	Still able to have a team experience A sense of community Feeling like part of a group Awareness that they were not alone Togetherness Belonging to a team Enjoyed the companionship that they received during practice Opportunity to participate in a "group" activity Teamwork and unity Need of togetherness Belonging A sense of connectedness with girls of the same age group
Higher-order theme: psychological growth	
Coping with stress	Mental health Managing negative feelings Cope with the world at the moment Allowed them to de-stress and focus on things outside the stress of everyday life Learn skills to cope with this stressful, constantly changing time Teaching girls coping skills Discussed coping skills for the stress of virtual school and sadness Strategies to cope with stress Spending time furthering their mental health needs
Building confidence	Reinforcing their confidence Sense of accomplishment after completing the 5 k Building confidence in what their bodies can do Opportunity to put some stress aside and become a stronger and more confident girl A chance to focus on their self-development Watched their confidence grow in expressing themselves
Higher-order theme: life skills development	
Learning life lessons	Positive mindset Opportunity to develop social skills (sharing, cooperation, overcoming shyness, productive disagreement and conflict resolution) Having lessons on emotions bridges gaps with how they are feeling and how they can express it The lessons about feelings and how to manage and communicate them were very helpful Participate in an outdoor activity with friends where they were learning important life skills Staying Positive Opportunity to learn about self-love and respect for others Developed skills to see their strengths, push themselves to reach their goal, and how to support each other Positive self-talk Learned tools which are very helpful to use in their everyday lives, especially during a time like now How to manage emotions Focusing on the positive Learning that people that bring you up are better to be around than people that bring you down Learning social skills "Star power" to build self confidence Lessons that incorporated feelings and how to handle them Learn great life skills during a difficult time Practicing coping methods for negative feelings and self-talk Able to build a toolbox of skills through the lessons Develop strong habits/practices in exercise, mental health, confidence, and relationships Team building skills Learning important life skills during a hard year Star Power
Higher-order theme: positive social environment	
Having a safe and supportive environment	Safety for the girls and coaches Safe, multipurpose, extracurricular activity A safe and healthy environment for the girls to discuss issues important to them Positive, meaningful, and real connection that kept safety the top priority Supporting each other Having a safe place to go where they could release some energy in a positive way Forming relationships with other girls in a positive and supportive environment

(Continued)

TABLE 4 | Continued

Lower-order theme:	Data units:
	Creating an environment for girls to support each other
	Having a safe and open space for them to share their thoughts and ideas
	Have meaningful discussions around topics being dealt with in daily lives
	A chance to talk about Covid in a safe setting
	Girls had a platform to share in their joys, excitement, triumphs, and hardships
	Time for girls to talk about their feelings
	Opportunities to chat about what was on their mind.
	Time for girls to talk about their feelings in a safe space
	A place where girls can be silly, a little less formal, and express themselves
	Opportunity for the girls to talk about their feelings
	The girls had exactly what they needed to participate safely
	Providing a safe space for girls to vent and enjoy time with one another
	A safe space to express emotions
	Gave them a sense of security
	Able to express their emotions
	Being able to talk with other people their age
	Surrounded by tons of positivity from girls their own age
	Allowed them to express themselves
	A safe place to express emotions and share experiences
Higher-order theme: having fun	
Having fun	Provided a sense of fun
	Enjoyed having a more laid back, social activity
	A fun way for the girls to connect
	Participate in fun games to take their mind off of things
	A place for girls to have fun
	Fun interaction and engagement
Higher-order theme: sense of normalcy during the pandemic	
Sense of normalcy during the pandemic	A piece of sanity in the midst of insane times
	Feeling a sense of normalcy and belonging
	Surrounded by their peers gave them some normalcy
	Gave the girls a sense of calm in all this chaos
	Focusing on growth and positivity during such a limiting and negative time was wonderful for them
	Great way to get girls moving during this pandemic where you have to spend a majority of time indoors
	Giving them something to look forward to during this time
	For many, this was their first time getting together with people outside of their family since before COVID
	Ability to have a routine
	Provided girls with stability during uncertain times
	Chance to be with other girls and stay active during this period of isolation
	Giving the girls something to look forward to twice a week
	Consistency—allow girls to continue participating in a meaningful program they enjoy and look forward to.
	Giving the girl something positive to do during this hard time
	The girls were able to be "normal" during our time together.
	Getting back to something somewhat normal!
	A feeling of normalcy–when so much has been canceled including almost all clubs, GOTR was there.
	A distraction from the pandemic

Life Skills Development was characterized by learning life lessons, such as adopting a positive mindset, managing emotions, developing social skills, and helping others. One coach explained, "… the opportunity to develop social skills (including sharing, cooperation, overcoming shyness, productive disagreement and conflict resolution), given that many aren't in school." Another said, "Many of the girls developed skills to help them see their strengths, push themselves to reach their goal, and how to support each other." One elaborated: "The girls were able to build a toolbox of skills through the lessons that helped them in this current odd environment … The girls learned that other girls felt the same way about life/the world. There was safety in knowing they were not alone."

Positive Social Environment was exemplified by having a safe and supportive space for engaging in activities and interacting with peers. A coach stated, "GOTR gave the girls something to look forward to and people to interact with. I think most of them were lonely and hadn't seen any peers in a while. GOTR gave them a space to talk about their lives and how they've been feeling." Other coaches stated, "This made connection possible outside of the household. Positive, meaningful, and real connection that kept safety the top priority", and "The program was able to help with providing a safe place for girls to connect while they are experiencing isolation due to the pandemic … the content was encouraging and helped to keep them positive and growing during a challenging time." The higher-order theme, Having Fun, also reflected a positive and supportive climate—enjoying activities with peers and fun games to take their mind off things (i.e., COVID).

Sense of Normalcy during the Pandemic depicted a theme specific to meeting girls' needs during COVID-19. One coach succinctly characterized GOTR's role, "A piece of sanity in the midst of insane times." Another exclaimed, "Getting back to something somewhat normal! For the time we were together, besides masks, distancing and sanitizer, it felt good to do something other than be on the computer at home all day." Another stated, "Normalcy. So many of our girls had things interrupted over the last 8 months and to bring the program back at our school was so helpful and nice to see them involved in an after-school activity".

DISCUSSION

Utilization-focused evaluation research is a means for bridging evidence-based findings with practical implications (11). It begins with the premise, "… evaluations should be judged by their utility and actual use … how real people in the real world apply evaluation findings" (p. 4). Patton states that evaluation research should answer three questions: *What* … changes in attitudes, skills, and behaviors occur in participants? *So What* … do the findings imply about the degree to which the program is considered a success? *Now What* … recommendations flow from the findings? We systematically address study findings relative to

these questions based on caregivers' and coaches' perceptions of safety protocol changes to curricula and delivery mode.

What changes in girls' attitudes, skills, and behaviors occurred by participating in GOTR? Quantitative responses by caregivers and coaches were favorable (e.g., my girl learned skills to handle stress associated with the pandemic), regardless of the curriculum delivered in-person, virtually, or hybrid. Caregivers reported girls as less lonely, more confident, and more physically active at season's end—for all modes. Qualitative themes provided detail for how girls were impacted by GOTR (caregivers) and what greatest need was met by participating during this challenging time (coaches). Based on these data, GOTR provided a means of sustaining physical activity, strengthening friendships, achieving goals, and building confidence. Girls acquired ability to express feelings, maintain optimism, and take pride in completing the 5 K. Evidence of season-long improvement in physical and psychosocial outcomes align with the mission, vision, and core values of the program (5) as well as longitudinal findings during "normal" program delivery (9, 10).

Qualitative data also revealed that learning life skills and feeling a sense of normalcy were central to countering the challenges girls faced, by acquiring skills to cope with stress, think positively, and develop relationships (6). Stakeholder groups credited GOTR with teaching life lessons that informed intentional decision-making (positive self-talk, choosing friends), managing negative emotions, and adopting healthy behaviors to navigate many areas of girls' lives during the pandemic. Ability to generalize lessons learned in GOTR to domains outside the program—school, family, peers—is a signature of PYD programs (2, 6).

So What … do findings imply about the degree to which GOTR was effective? Mixed methods revealed improvement in girls' physical activity and psychosocial attitudes and behaviors that infer program success using varied delivery modes and safety precautions. These promising outcomes occurred within a safe and supportive social environment that included encouraging coaches and meaningful peer interactions. "Social distancing" was not equivalent to reduced opportunities for socializing with peers, developing social skills, and experiencing a sense of community—innovative ways of delivering the program were successful in promoting PYD. Peer acceptance and close friendships are critical needs for youth in childhood and adolescence (15, 16), which was achieved through GOTR's quality programming and coach training. Building positive relationships is a key element of coach training, attained through activities that highlight cooperation, inclusion, support, and a mastery climate (5, 17). As a PA-PYD program challenged with modifying curricular lessons to accommodate safety precautions, GOTR was successful in providing an environment that made a positive impact on girls' physical activity and psychosocial and emotional growth and development.

Now What … recommendations can be made for program improvements? While favorable ratings emerged for all delivery modes, the virtual experience was rated lower for a few items (albeit small effect sizes). This included, "GOTR has been a valuable experience for my girl", "I formed positive relationships with girls on my team", and "girls on my team developed positive relationships with teammates." Satisfaction with a virtual end-of-season event was rated lowest. GOTR used the findings to recommend areas for improving the Spring 2021 season. First, councils were encouraged to conduct the end-of-season 5 K in person and at site-based locations if possible. Second, to optimize developing positive relationships, virtual session length was extended from 45 to 60 min and ideas were added to the virtual curriculum for coaches to make more informal connections. Third, a team workout option was added to the virtual curriculum (girls and coaches complete it together), which increased time for connection and motivation for physical activity.

Despite strengths of this study (e.g., mixed methods, multiple stakeholders), we note some limitations. First, 39 councils agreed to participate and, although large samples of caregivers and coaches from over 1,000 teams completed the survey, it is unknown how those in other councils viewed the program experience. Second, the sample was not as diverse as the makeup of the broader organization. Survey responses represented 25% girls of color, whereas the network composition for Fall 2020 was 37%. GOTR remains committed to gathering insights from individuals of diverse sociocultural backgrounds and is pursuing strategies to ensure representation. Third, to maximize return rate the survey length was kept reasonable, which did not allow for more quantitative items. The open-ended questions provided rich data to complement ratings and lent perspective on areas of holistic health and well-being attained through participating.

In conclusion, GOTR resourcefully and effectively applied COVID-19 safety precautions with in-person, virtual, and hybrid modes. All modes were received favorably and open-ended narrative revealed the breadth and depth of program impact. Evaluation findings provide GOTR and other youth programs with critical information for improving curricula, coach training, and program delivery while maintaining high safety protocols during a challenging health crisis.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the dataset is proprietary to Girls on the Run International. Requests about the data should be directed to Maureen Weiss, mrweiss@umn.edu.

ETHICS STATEMENT

The project was reviewed by Research Integrity and Compliance (RIC), Texas State University, San Marcos, TX, USA. Because the study exclusively involved the examination of anonymous, secondary data, the research is not regulated by RIC, and written informed consent for participation was not required.

AUTHOR CONTRIBUTIONS

MW and AR conceived the study. AR collected the data. MW and LK drafted the earlier versions of the manuscript and conducted the qualitative data analysis. LK conducted the quantitative data analysis. All authors contributed to revising the manuscript and approved the final submitted version.

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The Physical Fitness Level of College Students Before and After Web-Based Physical Education During the COVID-19 Pandemic

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Background: The COVID-19 pandemic has been an emergency worldwide. Web-based physical education is a choice for college students to keep on their study. The aim of this study was to compare the data of physical fitness of college students before and after web-based physical education.

Methods: All the students of 2018 and 2019 in Wuhan University of Technology who had taken the web-based physical education class in 2020 were included in this study. The records of annual physical fitness tests of all the subjects in 2019 and 2020 which were carried out in September were reviewed, including weight, height, body mass index (BMI), vital capacity (VC), 50-m dash, sit-and-reach, standing long jump, male-specific pull-ups and 1,000-m race, and female-specific sit-ups and 800-m race.

Results: There were 24,112 male and 9,690 female records of physical fitness tests included in our study. The results of 11,219 male and 4,651 female students who completed both physical fitness tests in 2019 and 2020 were employed for Wilcoxon signed-rank test. Declined performance was observed on male 50-m dash by 0.1 s, male 1,000-m race by 14 s, and female 800-m race by 11 s. Notably, the percentage of male obesity, based on BMI, rose from 10.6 to 15.2% and 17.1 to 21.8% for male overweight; correspondingly, the percentage of male normal weight declined from 55.9 to 51.9% and 16.4 to 11.1% for male thinness. The trend of increasing BMI in males should be paid attention to. Improved results on vital capacity, sit-and-reach, standing long jump for both males and females, female 50-m dash, female sit-ups, and male pull-ups were observed in 2020. All the results of physical fitness tests were significantly different between 2019 and 2020 ($p < 0.01$) by Wilcoxon signed-rank test.

Conclusions: The changes of physical fitness tests before and after web-based physical education suggested that the focus should be placed on improvement for running tests through appropriate alternatives, such as fast running in place and shuttle run. In addition, the simple, convenient, and practical sport that require available equipment and little field should be considered for web-based physical education.

Keywords: COVID-19, college students, physical education, physical fitness, exercise

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INTRODUCTION

The outbreak of coronavirus disease 2019 (COVID-19), caused by a novel coronavirus named SARS-CoV-2, has affected the health of millions of people (1), which has been declared as a pandemic by the World Health Organization. To prevent the further spread of this severe infectious disease, quarantine was considered an effective method to protect the uninfected people from COVID-19 (2). As reported, the pandemic would last for a rather long period (3), as well as the quarantine. Education was disrupted by the closure of schools worldwide due to quarantine, with more than 990 million students involved reported by the United Nations Educational Scientific and Cultural Organization (4).

Although the quarantine was essential to prevent the further spread of COVID-19, it may also have limited the engagement of students in sufficient levels of physical activity. However, sufficient physical activity is essential not only for maintaining the physical well-being but also for keeping mental health in adolescents (5). Also, Chekroud's study has described that physical exercise was associated with lower mental health burden (6). Furthermore, Brooks's study has stated their concern on psychological impact of quarantine during this pandemic (7).

As insufficient physical activity was observed among adolescents in 146 counties by Cardon (8), how to restore the interrupted physical education for maintaining physical health was more essential than ever during this pandemic quarantine. Furthermore, Deng's study has described that mental health was significantly correlated with regular and sufficient exercise during this COVID-19 pandemic (9).

In order to keep physical and mental health of the adolescents, physical education was essential. As conventional education was not available, web-based education was carried out as an optional choice. Web-based physical education has been carried out in many universities and colleges during spring 2020 in Wuhan, but as an outdoor course, there were many challenges for web-based physical education.

So far as we knew, the effectiveness of newly developed web-based physical education has never been evaluated. In addition, as a newly developed style of physical education, it is difficult to evaluate the effectiveness of it comprehensively. Although physical education promoting physical activity and fitness has been long recognized (10, 11), the degree of physical education on improving physical fitness was still a controversial issue (12–14). However, physical fitness tests were still effective and quantitive tools for measuring effectiveness of physical education. In Bao's study, physical fitness tests were used to evaluate the effectiveness of mandatory physical education of the university students in aspects of body composition, cardiorespiratory endurance, flexibility, muscular strength, and muscular endurance (15).

Therefore, the primary purpose of our study was to describe the results of physical fitness tests before and after Web-Based Physical Education during the COVID-19 pandemic, in 2019 and 2020 separately. Also, the secondary purpose of our study is to compare the results of physical fitness tests in 2019 and 2020, though it could not be only attributed to web-based physical education, the changes of physical fitness results could give out the insufficient aspects of college students and the suggestion for web-based physical education in the future.

Abbreviations: BMI, body mass index; VC, vital capacity.

METHODS

Study Population and Their Web-Based Physical Education

All the students of 2018 and 2019 in Wuhan University of Technology who had taken the web-based physical education class in 2020 were included in this study. The web-based physical education class was carried out once a week for 1 h and a half in 2020 spring. The time duration for warm-up, exercise, and relaxation was 15 min, 1 h, and 15 min, respectively. The exercise of web-based physical education class was chosen by students, including football, basketball, tennis, badminton, table tennis, gymnastics, and Chinese kung fu. Exercise for 1 h everyday was assigned as homework for all the students. This study was conducted in accordance with the Declaration of Helsinki and the ethical guidelines of medical research covering humans. This study was approved by institutional review board of Wuhan Children's Hospital (WHCH 2020029). Informed consents were disseminated by teachers to students and were provided by all the subjects.

Measurements of Physical Fitness Tests

The records of annually physical fitness tests of all the subjects in 2019 and 2020 which were carried out in September were reviewed. All the tests were measured and recorded by Lingkang physical fitness test set (Jiangsu Lingkang Electronic Technology, Changzhou, China). The physical fitness test was evaluated by the same group of physical education teachers in Wuhan University of technology in 2019 and 2020. All the tests were carried out during 8:30 a.m.−12:00 noon and 1:30 p.m.−5:00 p.m. The height and weight of each student were obtained at the beginning of physical fitness test. Height was obtained as the length from the highest point of head to the heel of students standing straight. Weight was measured as the students weigh without heavy clothing and shoes on. The physical fitness level of each student was quantified by seven tests, with body mass index (BMI), vital capacity (VC), 50-m dash, sit-and-reach, and standing long jump for both males and females, while sit-ups and 800-m race for females only, pull-ups and 1,000-m race for males only. Body mass index (BMI): a ratio of weight and height of the body, calculated as the ratio of the weight of the body in kilograms to the square of the height in meters. VC: a measurement for lung function, defined as the maximum amount of air in milliliters that can be exhaled after a maximum inhalation. Fifty-meter dash: to assess the speed and acceleration, measured as a single sprint of 50 m with time recorded in seconds. Sit-and-reach: to evaluate the flexibility, measured from sitting with legs outstretched, students reached hands forward as far as possible with length over foot recorded in centimeters. Sit-ups (for females only): to assess the muscle endurance, measured from supine position with legs bended, students rose from lying to a sitting position as many as possible over 60 s, with number

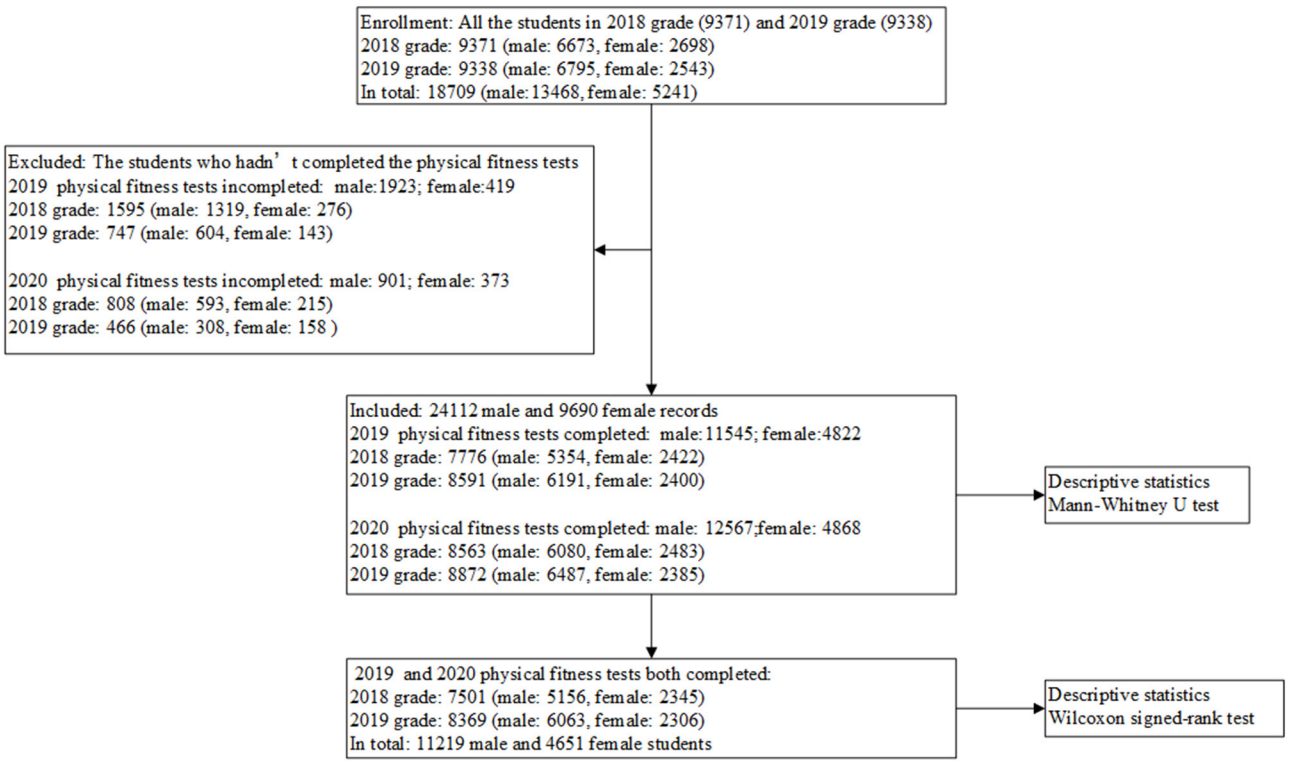

FIGURE 1 | Flow chart of this study.

of correctly executed sit-ups recorded. Pull-ups (for males only): to evaluate muscle endurance, measured from hanging by hands from a horizontal bar, students pulled themselves up until the chin is at the level of the bar as many as possible, with number of correctly executed pull-ups recorded. Standing long jump: to assess explosive strength, measured from standing at a mark, students tried to jump as far as possible, with length recorded in centimeters. 800-m (for female)/1,000-m (for males) race: to assess the endurance, measured as a race of 800 m/1,000 m with time recorded in seconds.

Statistical Analysis

The students who had not completed the physical fitness tests were excluded. The Kołmogorov–Smirnov test served to check normality. The descriptive statistics were used for all the results of physical fitness tests, including height (in cm), weight (in kg), BMI (in kg/m^2), vital capacity (in milliliters), 50-m dash (in s), sit-and-reach (in cm), male-specific pull-ups and female-specific sit-ups (by count), standing long jump (in cm), and male-specific 1,000-m race and female-specific 800-m race (in s). The results of physical fitness tests were expressed as mean and 95% confidence interval as well as median and interquartile range, according to the normality test. Classification evaluation of physical fitness tests was according to the National Physical Health Standards for Students (revised in 2014) (16), BMI was evaluated according to Ko's study as lower BMI cutoff value has been suggested for Chinese (17), and Chi-square test was employed to compare the difference of physical fitness tests between 2019 and 2020. Mann–Whitney U test was used for comparing the differences of physical fitness tests of all included subjects between 2019 and 2020. The students who completed both physical fitness tests in 2019 and 2020 were included for Wilcoxon signed-rank test. The significant level was set at $p < 0.01$. SPSS Statistic 19.0 (IBM SPSS Statistics, New York, USA) was employed for statistical analysis.

RESULTS

Subjects Characteristics

There were 9,371 students (male: 6,673, female: 2,698) in the 2018 grade and 9,338 (male: 6,795, female: 2,543) students in the 2019 grade. The students who had not completed the physical fitness tests were excluded. At last, there were 7,776 (male: 5,354, female: 2,422) in the 2018 grade and 8,591 (male: 6,191, female: 2,400) in the 2019 grade who had completed the physical fitness tests of 2019, 8,563 (male: 6,080, female: 2,483) in the 2018 grade, and 8,872 (male: 6,487, female: 2,385) in the 2019 grade who had completed the physical fitness tests of 2020 being included in this study. in total, there were 24,112 male and 9,690 female records of physical fitness tests being included in our study.

There were 11,219 male and 4,651 female students who completed both physical fitness tests in 2019 and 2020. The results of their all physical fitness tests were employed for Wilcoxon signed-rank test. The flow chart is shown in **Figure 1**.

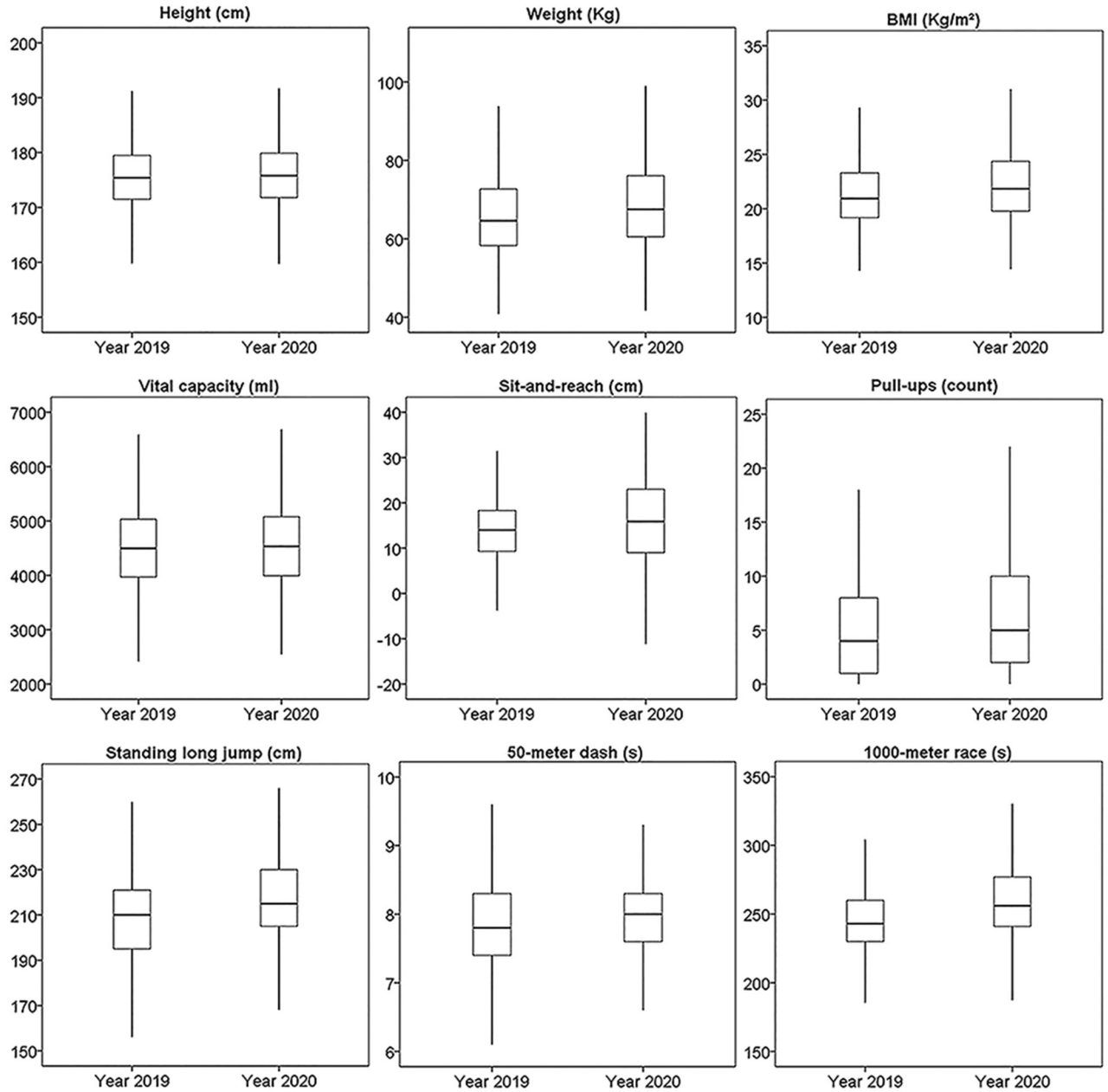

FIGURE 2 | The boxplots of nine results of physical fitness tests from 24,112 male records. Middle line in the box represents the median. The upper and lower boundaries of the box represent upper and lower quartiles. The endpoints of whiskers represent upper and lower extremes.

Descriptive Statistics and Mann–Whitney *U* Test for all Included Subjects

As the data was not normally distributed, it was presented as median and interquartile range. The median and interquartile range of all the physical fitness tests were presented for males and females in **Figures 2**, **3**, separately.

Classification evaluation of physical fitness tests from 24,112 male and 9,690 female records is shown in **Table 1**. Notably, the percentage of male obesity, based on BMI, rose from 10.6 to 15.2% and 17.1 to 21.8% for male overweight; correspondingly, the percentage of male normal weight declined from 55.9 to 51.9% and 16.4 to 11.1% for male thinness.

All the results of physical fitness tests from male records were significantly different between 2019 and 2020 with $p < 0.001$. While except for BMI ($p = 0.541$), all the other results of physical fitness tests from female records were significantly

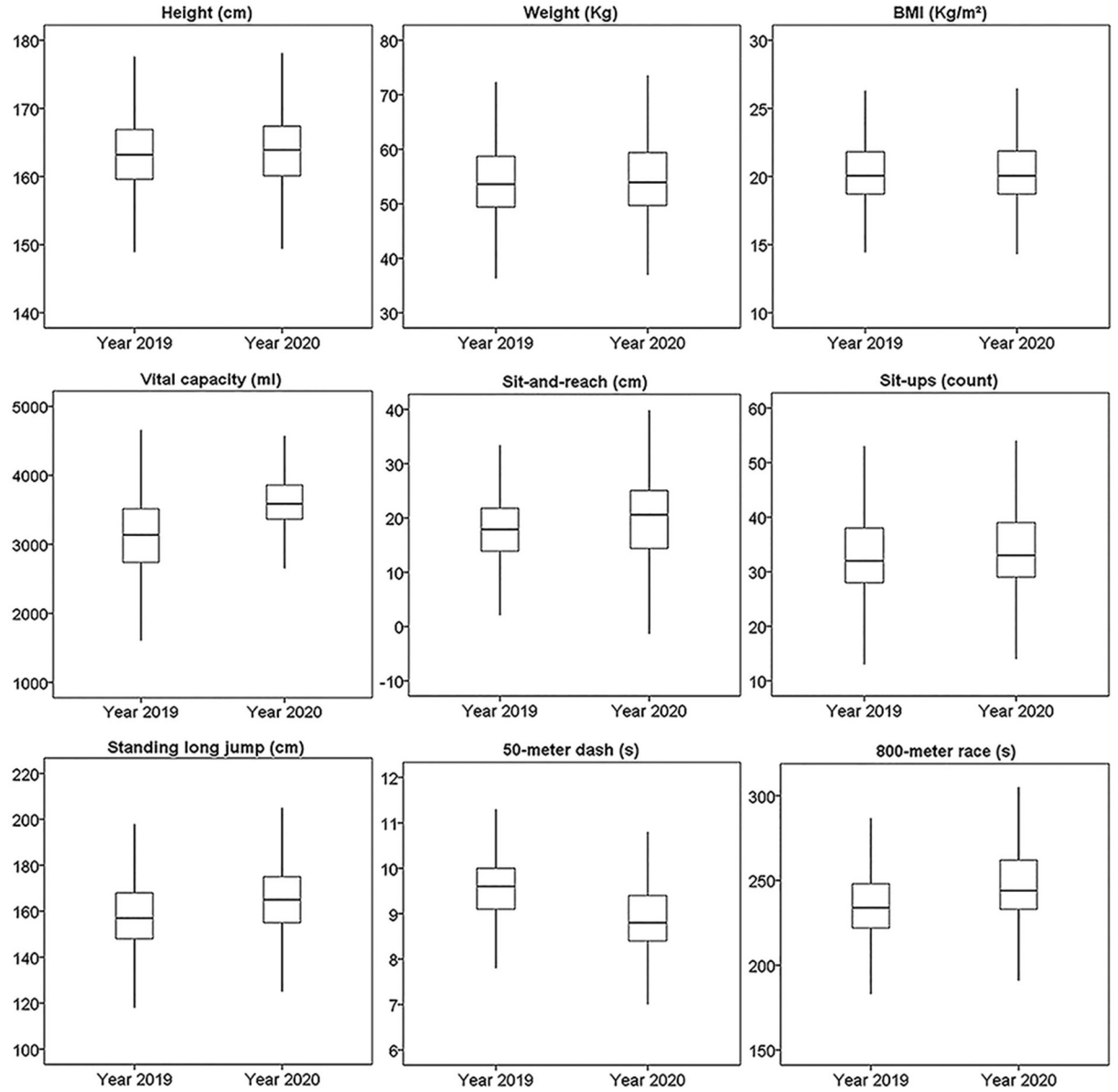

FIGURE 3 | The boxplots of nine results of physical fitness tests from 9,690 female records. Middle line in the box represents the median. The upper and lower boundaries of the box represent upper and lower quartiles. The endpoints of whiskers represent upper and lower extremes.

different between 2019 and 2020 ($p = 0.001$ for weight; $p < 0.001$ for height, vital capacity, 50-m dash, sit-and-reach, sit-ups, standing long jump, and 800-m race).

Descriptive Statistics and Wilcoxon Signed-Rank Test for Subjects Completed Both Physical Fitness Tests in 2019 and 2020

The mean and 95% confidence interval of physical fitness tests in 2019 and 2020 from 11,219 male and 4,651 female students are shown in **Figures 4**, **5** separately, all the subjects had completed both physical fitness tests in 2019 and 2020. The median, median of difference, and the *p*-value of 2019 and 2020 from these subjects is shown in **Table 2**. The *p*-value for all the results of physical fitness tests from 11,219 male students and 4,651 female students was <0.001. Notably, declined performance was observed on male 50-m dash by 0.1 s, male 1,000-m race by 14 s, and female 800-m race by 11 s.

DISCUSSION

Under the circumstance of quarantine, the significant reduction of physical condition was first observed in professional athletes (18–21). However, the physical fitness of adolescents should be paid special attention to because of the reduction of

TABLE 1 | Classification evaluation of physical fitness tests from 24,112 male and 9,690 female records.

	Male in 2019	Male in 2020	Female in 2019	Female in 2020
Age (year)	$p < 0.001$			$p < 0.001$
≤17	1,730 (15.0%)	112 (0.9%)	757 (15.7%)	48 (0.9%)
18	5,115 (44.3%)	1,715 (13.6%)	2,190 (45.4%)	701 (14.4%)
19	3,841 (33.3%)	5,457 (43.4%)	1,614 (33.5%)	2,203 (45.3%)
20	695 (6.0%)	4,292 (34.2%)	214 (4.4%)	1,629 (33.5%)
21	130 (1.1%)	789 (6.3%)	37 (0.8%)	235 (4.8%)
≥22	34 (0.3%)	202 (1.6%)	10 (0.2%)	52 (1.1%)
BMI (kg/m^2)	$p < 0.001$			$p = 0.559$
Thinness (<18.5)	1,889 (16.4%)	1,397 (11.1%)	1,040 (21.6%)	1,012 (20.8%)
Normal (≥18.5 and <23)	6,452 (55.9%)	6,519 (51.9%)	3,090 (64.1%)	3,113 (63.9%)
Overweight (≥23 and <26)	1,979 (17.1%)	2,745 (21.8%)	503 (10.4%)	539 (11.1%)
Obesity (≥26)	1,225 (10.6%)	1,906 (15.2%)	189 (3.9%)	204 (4.2%)
VC (ml)	$p < 0.001$			$p < 0.001$
Excellent (≥4,800 for male, ≥3,300 for female)	4,084 (35.4%)	4,665 (37.1%)	1,879 (39.0%)	4,231 (86.9%)
Good (≥4,300 and <4,800 for male, ≥3,000 and <3,300 for female)	2,834 (24.5%)	3,522 (28.0%)	972 (20.2%)	593 (12.2%)
Pass (≥3,100 and <4,300 for male, ≥2,000 and <3,000 for female)	4,376 (37.9%)	4,288 (34.1%)	1,900 (39.4%)	44 (0.9%)
Fail (<3,100 for male, <2,000 for female)	251 (2.2%)	92 (0.8%)	71 (1.4%)	0 (0.0%)
50-m dash (s)	$p < 0.001$			$p < 0.001$
Excellent (≤6.9 for male, ≤7.7 for female)	736 (6.4%)	276 (2.2%)	45 (0.9%)	40 (0.8%)
Good (≤7.1 and >6.9 for male, ≤8.3 and >7.7 for female)	712 (6.2%)	459 (3.7%)	162 (3.4%)	905 (18.6%)
Pass (≤9.1 and >7.1 for male, ≤10.3 and >8.3 for female)	9,743 (84.4%)	11,714 (93.2%)	3,967 (82.3%)	3,334 (68.5%)
Fail (>9.1 for male, >10.3 for female)	354 (3.0%)	118 (0.9%)	648 (13.4%)	589 (12.1%)
Sit-and-reach (cm)	$p < 0.001$			p <0.001
Excellent (≥21.3 for male, ≥22.2 for female)	1,581 (13.7%)	3,995 (31.8%)	1,039 (21.5%)	2,084 (42.8%)
Good (≥17.7 and <21.3 for male, ≥19 and <22.2 for female)	1,756 (15.2%)	1,555 (12.4%)	1,033 (21.4%)	850 (17.5%)
Pass (≥3.7 and <17.7 for male, ≥6 and <19 for female)	7,639 (66.2%)	6,406 (50.9%)	2,668 (55.3%)	1,797 (36.9%)
Fail (<3.7 for male, <6 for female)	569 (4.9%)	611 (4.9%)	82 (1.8%)	137 (2.8%)
Pull-ups/sit-ups (count)	$p < 0.001$			$p < 0.001$
Excellent (≥17 for male, ≥52 for female)	243 (2.1%)	189 (1.5%)	97 (2.1%)	112 (2.3%)
Good (≥15 and <17 for male, ≥46 and <52 for female)	224 (2.0%)	159 (1.3%)	267 (5.5%)	309 (6.3%)
Pass (≥10 and <15 for male, ≥26 and <46 for female)	1,861 (16.1%)	2,807 (22.3%)	3,814 (79.0%)	4,137 (85.0%)
Fail (<10 for male, <26 for female)	9,217 (79.8%)	9,412 (74.9%)	644 (13.4%)	310 (6.4%)
Standing long jump (cm)	$p < 0.001$			p <0.001
Excellent (≥263 for male, ≥195 for female)	49 (0.4)	172 (1.4%)	122 (2.6%)	481 (9.9%)
Good (≥248 and <263 for male, ≥181 and <195 for female)	280 (2.4%)	708 (5.6%)	265 (5.5%)	384 (7.9%)
Pass (≥208 and <248 for male, ≥151 and <181 for female)	6,372 (55.2%)	8,231 (65.5%)	3,006 (62.3%)	3,439 (70.6%)
Fail (<208 for male, <151 for female)	4,844 (42.0%)	3,456 (27.5%)	1,429 (29.6)	564 (11.6%)
1,000-m/800-m race (s)	$p < 0.001$			p <0.001
Excellent (≤207 for male, ≤210 for female)	382 (3.3%)	407 (3.2%)	408 (8.5%)	288 (5.9%)
Good (≤222 and >207 for male, ≤224 and >210 for female)	1,373 (11.9%)	547 (4.4%)	1,057 (21.9%)	472 (9.7%)
Pass (≤272 and >222 for male, ≤274 and >224 for female)	8,299 (71.9%)	7,885 (62.7%)	3,113 (64.6%)	3,458 (71.0%)
Fail (>272 for male, >274 for female)	1,491 (12.9%)	3,728 (29.7%)	244 (5.0%)	650 (13.4%)

cm, centimeter; kg, kilogram; kg/m^2, kilogram/meter^2; ml, milliliter; s, second.

physical activity reported recently (22–24). Considering the protection of physical activity on physical and mental health, Chen recommended regular physical activity and routinely exercising in a safe home environment (25). Furthermore, physical education teacher could improve the physical fitness more significantly than generalist teacher reported by Starc (26), specialist physical education was irreplaceable. Therefore, web-based physical education is a safe and new style for college students under this shutdown. However, the change of physical fitness before and after the web-based physical education has never been described so far as we know. The physical fitness tests in our study could represent the body composition (represented by height, weight, and BMI), cardiorespiratory function (represented by vital capacity and 1,000/800-m race),

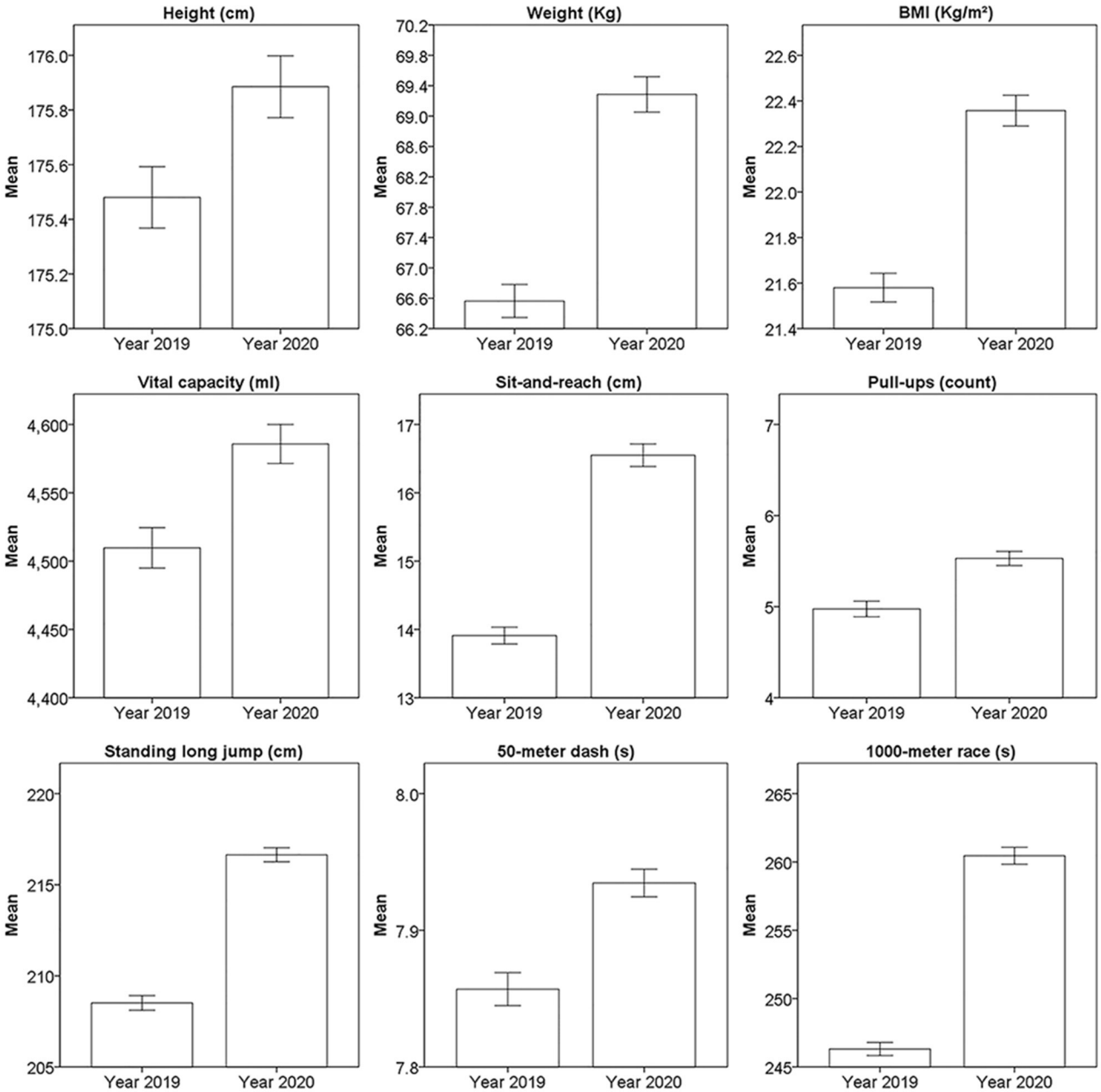

FIGURE 4 | The mean and 95% confidence interval of physical fitness tests from 11,219 male students.

flexibility (represented by sit-and-reach), strength of muscle (represented by standing long jump and 50-m dash), and endurance of muscle (represented by pull-ups for male/sit-ups for female and 1,000/800-m race). The different change of result from each test would reflect the disadvantage of physical fitness and the focus of web-based teaching in the future.

As to the body composition, we would like to discuss the height, weight and BMI together, as the students were still growing adolescents. The height of both male and female student increased in 2020 along with the time because of the growing development, as well as the weight. According to the suggested BMI for Chinese, 18.5 $\leq$ BMI $<$23 was considered normal (17). The percentage of male obesity rose from 10.6 to 15.2% and 17.1 to 21.8% for male overweight; correspondingly, the percentage of male normal weight declined from 55.9 to 51.9% and 16.4 to 11.1% for male thinness. Significantly increased percentage of male obesity and overweight in 2020 meant the increase of weight gain exceeding the height, which may suggest insufficient exercise or excessive intake of food. As obesity has been considered a chronic relapsing disease process now, healthy

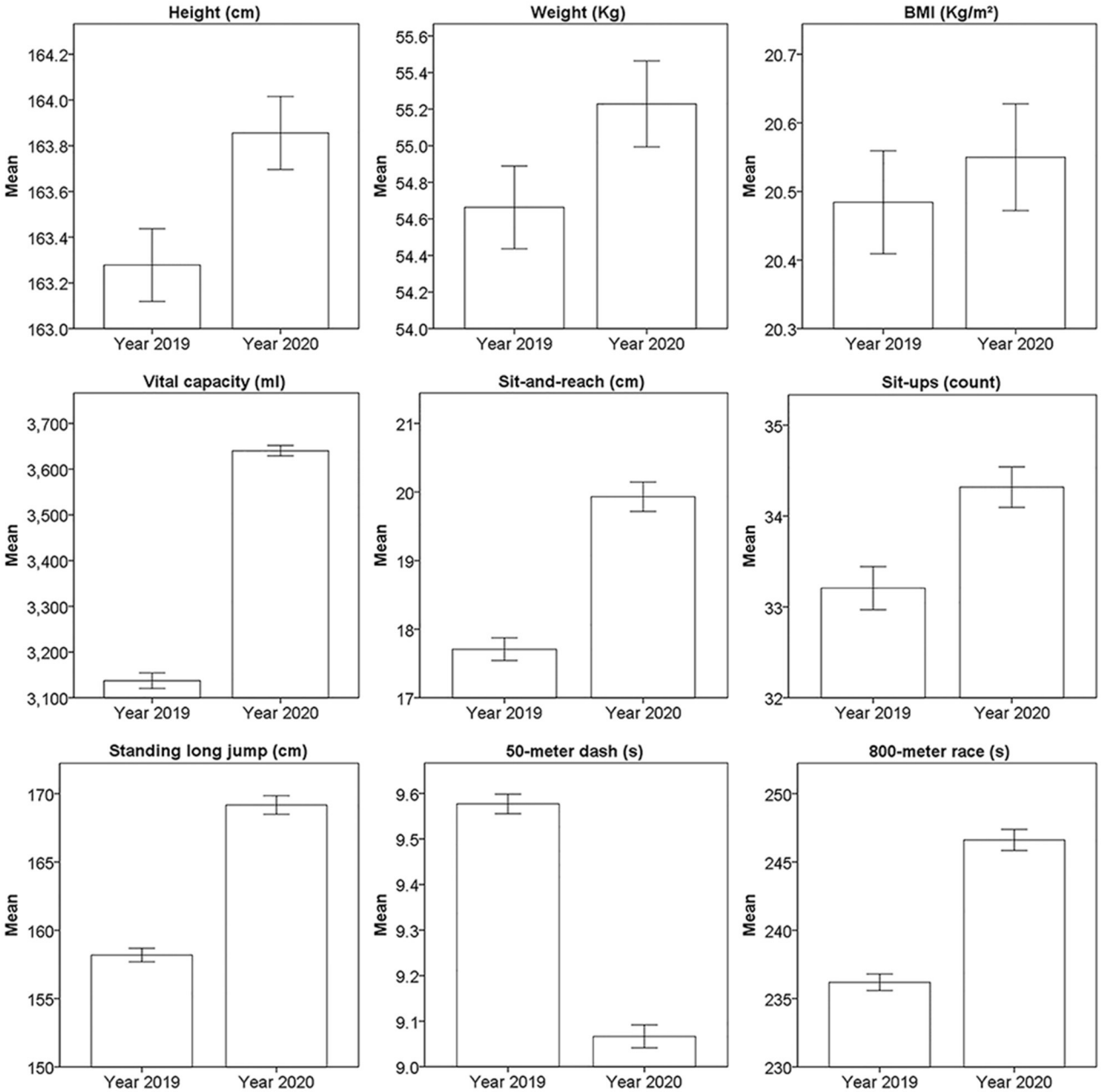

FIGURE 5 | The mean and 95% confidence interval of physical fitness tests from 4,651 female students.

life style including proper exercise is essential for keeping normal BMI (27). Hallal's team has reported that males were more positive in exercise than females (28), and their engagement in sports may be interrupted more severely by quarantine which resulted in insufficient exercise. Although the BMI of majority of males was still in normal range, sufficient exercise should be restored in order to prevent obesity and its detrimental effects.

Quanjer's work has reported the reference values of vital capacity which is an essential index for lung function (18). The interquartile range of vital capacity in our work basically fell in to the reference values by Quanjer's team. As no relationship between BMI and vital capacity was found by previous reports (20, 24), the change of vital capacity could not be explained only by the natural growing development. In our study, significant difference was noticed on vital capacity between 2019 and 2020, especially for female. According to Dugral's study, exercised young adults exhibited better vital capacity, especially for females. In addition, they suggested that lack of exercise significantly worsened the lung function (29). Considering our results on vital capacity, a certain amount of exercise should have been carried

TABLE 2 | The comparison of physical fitness tests between 2019 and 2020 from 11,219 male students and 4,651 female students.

	Male in 2019 (median, interquartile ranges)	Male in 2020 (median, interquartile ranges)	Median of difference, interquartile ranges	*p*-Value	Female in 2019 (median, interquartile ranges)	Female in 2020 (median, interquartile ranges)	Median of difference, interquartile ranges	*p*-Value
Age (year)	18, 18–19	19, 19–20	1, 1–1	<0.001	18, 18–19	19, 19–20	1, 1–1	<0.001
Height (cm)	175.4, 171.5–179.5	175.8, 171.9–179.9	0.4, −0.2–1.0	<0.001	163.2, 159.6–1,660.9	163.8, 160.0–167.4	0.5, −0.2–1.3	<0.001
Weight (kg)	64.6, 58.2–72.5	67.3, 60.4–75.9	2.4, 0.2–5.2	<0.001	53.5, 49.4–58.6	53.9, 49.7–59.3	0.6, −1.2–2.4	<0.001
BMI (kg/m^2)	20.9, 19.2–23.3	21.8, 19.7–24.3	0.7, 0.0–1.6	<0.001	20.1, 18.7–21.8	20.0, 18.7–21.9	0.1, −0.6–0.8	<0.001
VC (ml)	4,497, 3,970–5,028	4,537, 3,997–5,074	77, −278–432	<0.001	3,140, 2,742–3,515	3,588, 3,367–3,857	434, 63–928	<0.001
50-m dash (s)	7.8, 7.4–8.2	7.8, 7.6–8.3	0.1, −0.3–0.5	<0.001	9.6, 9.1–10.0	8.8, 8.4–9.4	−0.6, −1.1–0.0	<0.001
Sit-and-reach (cm)	14.0, 9.4–18.4	16.0, 9.2–23.1	1.6, −2.8–7.6	<0.001	18.0, 14.0–21.8	20.7, 14.6–25.2	1.5, −2.3–6.3	<0.001
Pull-ups/sit-ups (count)	4, 1–8	5, 2–10	0, −2–3	<0.001	33, 28–38	33, 29–39	1, −3–5	<0.001
Standing long jump (cm)	210, 195–222	215, 205–230	7, −3–19	<0.001	157, 148–168	165, 155–175	5, −3–15	<0.001
1,000-m/800-m race (s)	243, 229–259	256, 241–276	14, 0–29	<0.001	234, 222–248	244, 233–262	11, 0–23	<0.001

cm, centimeter; kg, kilogram; kg/m^2, kilogram/meter^2; ml, milliliter; s, second.

out by the subjects in our study. At least, absence of physical activity was not observed in our study because of improved vital capacity.

As previous studies have reported, quarantine has already negatively influenced the physical activity level of youngsters and adolescents in Norway and Germany (30, 31). However, significant improvement was observed in sit-and-reach, male-specific pull-ups, female-specific sit-ups, and standing long jump in our study, which represented flexibility, muscular strength, and muscular endurance separately. Under the circumstance of quarantine, the physical activity mentioned above could still be carried out readily without being influenced by restriction of field and equipment, which was in accordance with the report of protection factor for maintaining physical activity level by use of home exercise equipment during this shutdown from Fearnbach's group (32).

As reported by Scheer, the events that limited by distance and time was significantly decreased during this pandemic, and they suggested that it was impossible that running events could return to pre-pandemic levels soon (33). Negative influence on running tests was observed on male 50-m dash and 1,000-m/800-m race in our study as well. Under the circumstance of shutdown, we supposed that inadequate practice on running due to unavailable field led to worse results in 2020. However, the improvement on female 50-m dash suggested that muscular strength could be improved even under this quarantine. Though the reason for this improvement was still not clear, we supposed it may be related to relatively stable BMI in females and appropriate alternative exercise for 50-m dash on muscular strength, according to previous reports by Chen (24). Further study would be carried out to search for alternative exercises not only on muscular strength but also for endurance of muscle.

Under this circumstance of shutdown, health-related life style should be restored, especially for adolescents (13, 34). As physical education teacher plays an irreplaceable role in the education, and web-based physical education was the new and safe choice for college students, we would like to know the focus of web-based physical education under this pandemic. The physical fitness tests before and after the web-based physical education could reflect the changes of physical condition in college students during this shutdown. Although there were many confounding factors, such as family socioeconomic status, local neighborhood, accessible sport facility, and exercise habit, physical education still played an important role on physical fitness in college students (12). Negative influence has been observed on BMI, male 50-m dash and 1,000-m/800-m race, while improvement on all the other tests was surprising. We could draw the conclusion that the development of physical fitness was unbalanced. The improved results on cardiorespiratory function (represented by vital capacity), flexibility (represented by sit-and-reach), strength of muscle (represented by standing long jump), and endurance of muscle (represented by pull-ups for male/sit-ups for female) in 2020 may be related to their simple, convenient, and practical implement. While the worse results on running tests may be related to restricted sports facility. According to Chen's and de Sa-Caputo's suggestion, the sports that only required available equipment and little field would be more recommendable, such as sit-ups, pull-ups, sit-and-reach, and Tai Ji Quan (23, 25). We suggested that web-based physical education should choose sports which were more convenient and implementable. In addition, the exercise as the alternatives for 50-m dash and 800/1,000-m race should be taken into consideration for web-based physical education, such as fast running in place and shuttle run which just needed little field. Furthermore, we could

gain experience from other courses and obtain support from emerging fields, such as virtual reality (35).

There were several limitations in our study. First, as the sudden outbreak of COVID-19 pandemic, prospective study was unavailable under this circumstance, and the subjects in our study may not represent the sample for Chinese students. Second, the confounding factors were not controlled in our study, such as physical education class selection, completion of homework, location of the students, social economic status, mental status, psychometric evaluation, sleep disorders, etc.; the results of physical fitness could not be explained as the effect of web-based physical education simply, but the latter one should be one of the important factors of the former one, according to previous studies (11, 26, 36).

CONCLUSIONS

The declined performance on male 50-m dash, male 1,000-m race, and female 800-m race was observed in 2020 after web-based physical education. The trend of increasing BMI in males should be paid attention to. While improved results on vital capacity, sit-and-reach, standing long jump for both males and females, female 50-m dash, female sit-ups, and male pull-ups were obtained in 2020. The changes of physical fitness tests before and after web-based physical education suggested that the focus should be placed on improvement for running tests through appropriate alternatives, such as fast running in place and shuttle run.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of Wuhan Children's Hospital (WHCH 2020029). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

WX, CH, YG, MG, and CD: conception and design of the study. WX, CH, YG, MG, MH, JD, and CD: data collection. WX, CH, YG, MG, MH, JD, and CD: analysis and interpretation of data. WX and CD: drafting the article. WX, CH, and CD: literature review. All authors critically revising the article, final approval of the manuscript, and have verified the collected data.

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Measurement Properties of Canadian Agility and Movement Skill Assessment for Children Aged 9–12 Years Using Rasch Analysis

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The Canadian Agility and Movement Skill Assessment (CAMSA) was recently widely used to assess fundamental motor skills in children. Although the CAMSA is reported to be reliable and valid, its measurement properties are not clear. This study aimed to examine the measurement properties of the CAMSA in a sample of Chinese children using Rasch analysis. The study sample was from 1,094 children aged 9–12 years in Zunyi City, Guizhou Province. Descriptive data were analyzed using SPSS 24.0 software, and the dichotomous data were analyzed by Winsteps version 4.5.4 and Facets 3.67.1 software performing Rasch analysis. The present study investigated CAMSA measurement characteristics by Rasch analysis, including the reliability of the rating instrument, unidimensionality, item-fit statistics, and differential item functioning (DIF). Inter-rater reliability and retest reliability showed that the CAMSA had a good internal consistency. Rasch analysis indicated that the CAMSA was unidimensional, locally independent, and had a good item-fit-statistic. Additionally, the CAMSA displayed a good fit for the item separation index ($12.50 > 2.0$), as well as for item reliability ($0.99 > 0.90$). However, the item difficulty of the CAMSA did not fit well with personal ability, and a significant DIF was found across genders. In the Chinese children sample test, the CAMSA demonstrated appropriate goodness-of-fit validity and rater reliability. Thus, future research will explore item difficulty and person ability fit, as well as DIF across genders.

Keywords: agility, motor skills, assessment, Rasch analysis, CAMSA

INTRODUCTION

Children's fundamental motor skills (FMS) have long been described as a cornerstone of their physical activity, and they are typically classified into movement skills (e.g., running, sliding), object control skills (e.g., catching, kicking), and stability skills (e.g., balance) (1, 2). Proficiency in these skills has an important implication for children's healthy development (3, 4), yet numerous studies have indicated that the global rate of children's mastery is low (5). The development of FMS in childhood is crucial for the development of individuals as they develop through life. Therefore, the

ideal FMS assessment tool should be provided during childhood, not only for diagnosing levels of motor skill development but also for targeting children's development in relation to motor skills.

Currently, numerous assessment tools are available internationally to assess children's FMS, such as TGMD (6, 7), MABC (8, 9), KTK (10, 11), and BOT (12, 13). A common feature of these assessment tools is that each movement is measured independently, and actions are not connected. These motor skill assessments accurately measure the completion of movements; however, the "real sport situation" is ignored, and the measurement results may deviate from an actual context (14). Contrary to these traditionally popular assessment tools, the Canadian Agility and Movement Skill Assessment (CAMSA) is the first international closed-loop motor skills assessment tool based on a series of combined movements (15). This assessment model is more closely matched to "real sport situations." The term "real sport situation" refers to the fact that the movements in the assessment are coherent, continuous, and highly similar to the practical movement situation (16, 17). Additionally, the test results of this real sports can better reflect what is happening during children's movements. Initially, the CAMSA was developed to measure children's fundamental, complex, and integrated motor skills, with the primary purpose of diagnosing the level of motor development and identifying the risk of motor disorders in children (15). Since then, the CAMSA has been widely and concurrently used as a critical component of the Canadian Assessment of Physical Literacy (CAPL) (18). The Children's Physical Literacy Assessment application showed that the CAMSA assessment results were similar to real sport situations (19).

Numerous studies from Canada (20), Australia (2), the Netherlands (21), the United Kingdom (22), South Africa (23), and China (19) have explored the measurement properties of the CAMSA instrument. However, validity of the CAMSA test has only been reported in three studies to date (except the CAMSA development team) (2, 19, 20). Of these, Lander et al. showed that CAMSA skill scores had good concurrent validity ($r_s = 0.68$) and inter-rater retest reliability (ICC = 0.85) in an Australian study of early adolescent girls (2). Another study from Canada validated the reliability and validity of the PLAY*fun* using the CAMSA as a validity criterion (20). The PLAY*fun* is an instrument with similar functions to the CAMSA, and it is also used to measure children's motor proficiency. A study by Stearns et al. revealed moderate to large correlations between PLAYfun and CAMSA ($r = 0.47$–0.60) (20). Furthermore, another study from a sample of Chinese male children explored the validity of the CAMSA timing test in comparison to three commonly used agility tests (19).

In the original study, the validity of the CAMSA was determined using the expert Delphi method. ANOVA was used to examine age and gender differences, and paired *t*-tests were conducted to examine differences between the effects of footwear vs. no footwear, as well as indoors vs. outdoors (15). Despite some studies further confirming the validity of the CAMSA skills assessment instrument (2, 20), processing data from the assessment results are inadequate. In particular, as a dichotomous data variable for the results of each CAMSA item, Rasch analysis is an effective method for processing this category of data (14, 24, 25). However, there are currently no studies that have applied Rasch analysis to establish the validity of the CAMSA. Additionally, although the validity of the CAMSA has been demonstrated in both Canadian and Australian children, there is no reported evidence of its validity among Chinese children (14). Therefore, this present study aimed to validate the measurement properties of the CAMSA skills test instrument for Chinese children using Rasch analysis.

METHODS

Participants

Clauser and Mazor stated that the sample size should not be too small if DIF analysis were to be conducted, with more than 500 participants at least (26). However, Mara and Angoff argued that, when the sample size was too large, the slightest difference in the test would be highly significant, increasing the probability of type I errors (27, 28). Therefore, the proposed collection of a sample of approximately 1,000 children aged 9–12 years is appropriate for this study. In addition, considering the gender balance of the participants, it would be sufficient for the gender ratio of children in each age group to be approximately equal. Therefore, at least 250 children should be included in each age group. Finally, a total of 1,094 children were recruited from six elementary schools in Zunyi, Guizhou Province, between October 8, 2019, and November 30, 2019. All children included should be physically non-disabled (no physical disabilities) and devoid of congenital disorders (e.g., heart disease).

Instruments

The CAMSA is a movement capability assessment tool developed by Longmuir et al. for children aged 8–12 years (15). The CAMSA is used to assess children's fundamental movement skills and assess their capability to combine simple and complex movements. The CAMSA consists of seven movement items: two-foot jumping (2 points), sliding (3 points), catching (1 point), throwing (2 points), skipping (2 points), one-foot hop (2 points), and kicking (2 points) (**Figure 1**). The scoring points for each item are scored on a one-point scale (0–1). The skill score of the CAMSA is the total number of correctly completed skill movements and the total score ranges from 0 to 14 (15, 18). More details on CAMSA movement scoring can be found in the Canadian Assessment of Physical Literacy, Second Edition (CAPL-2, https://www.capl-ecsfp.ca) (29).

Anthropometric measurements were performed using the standard protocol of the "National Student Physical Fitness Standards" (NSPFS, 2014 revised version) (Ministry of Education of the People's Republic of China, 2014). The GJH1211 electronic tester was used to measure the height and weight of the participants, and the children were required to be barefoot and wear light clothing for the measurements. The test scale values were 0.1 cm for height and 0.1 kg for weight. The participants' body mass index (BMI) was calculated using BMI = height/weight^2 (m/kg^2). The BMI scoring criteria developed by the NSPFS were as follows. For boys: 9 years old (overweight 19.5–22.1, obesity ≥22.2, low weight ≤13.8); 10 years old (overweight 20.2–22.6, obesity ≥22.7, low weight

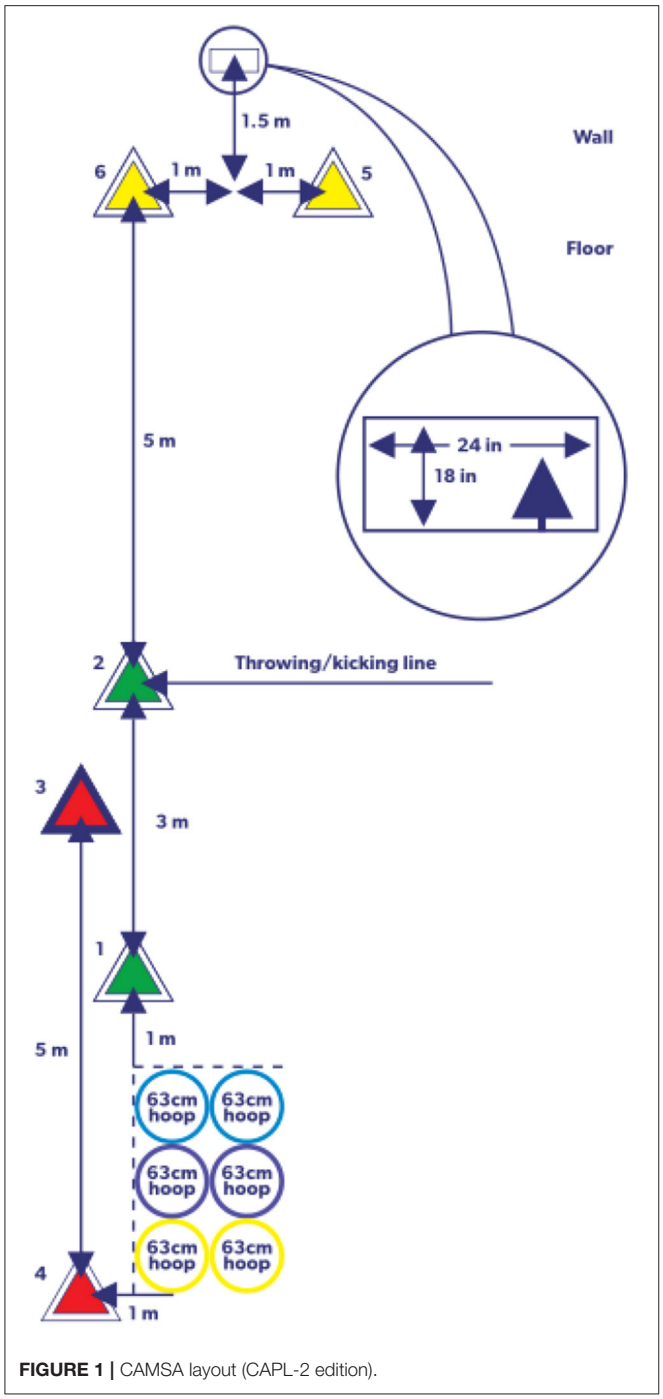

FIGURE 1 | CAMSA layout (CAPL-2 edition).

≤14.1); 11 years old (overweight 21.5–24.1, obesity ≥24.2, low weight ≤14.3); 12 years old (overweight 21.9–24.5, obesity ≥24.6, low weight ≤14.6). For girls: 9 years old (overweight 18.7–21.1, obesity ≥21.2, low weight ≤13.5); 10 years old (overweight 19.5–22.0, obesity ≥22.1, low weight ≤13.6); 11 years old (overweight 20.6–22.9, obesity ≥23.0, low weight ≤13.7); 12 years old (overweight 20.9–23.6, obesity ≥ 23.7, low body weight ≤14.1) (30).

Procedures

This study was approved by the Ethics Committee of the Institute of Motor Quotient, Southwest University (IRB No: SWUIMQ20190516). The study protocol was guided by the guidelines of the International Declaration of Helsinki. All participants had obtained written permission from their parents/guardians in the study.

A total of 1,927 children from six schools went home with a CAMSA test presentation, a parent/guardian consent form, and a student demographic questionnaire. One week later, 1,366 signed parental consent forms and demographic questionnaires were received. Investigators screened the demographic information forms, and 61 children were excluded (21 children had physical defects and 40 children were assessed for rater consistency). Finally, the number of participants that actually completed the entire test and were included in this study came to 1,094.

The six raters underwent rigorous training in CAMSA testing and proficiently mastered the administration process and movement commands of the CAMSA assessment (15). Before formal testing, 40 students (five per age group, male and female) were randomly selected from one school and scored by six raters to ensure consistency in the assessment scale. Two raters were allocated to a team, with one team as primary and the other two as secondary in the scoring test. The three scoring teams took turns to be primary and secondary. The entire test was videotaped. After 1 week of the testing interval, six raters were asked to rate the video again. The data from the on-site test were used for inter-rater reliability testing, and the data from the two tests were examined for retest reliability. The formal test was only administered when the scores of the six raters met the consistency test criteria.

The children watched two demonstrations of the test movements before testing, in accordance with the CAMSA manual. The raters explained the movements and guidance words to the children during the video demonstrations. The children were given two practice trials and two scored trials. Scores on the best of the two tests were used as final scores. Testing was conducted outside and was suspended in the event of rain. Generally, the tests were performed in physical education classes or during extracurricular activities. One physical education teacher was scheduled to assist in the administration of the children, and the assessors were only responsible for the scoring and timing. During the assessment process, two raters alternated in rating and timing in accordance with the subgroups.

Statistical Analysis

Descriptive statistical analyses were performed using SPSS 24.0 software to capture the demographic characteristics of the participants, including gender, age, and BMI. Rasch analysis was conducted to verify the construct validity of the CAMSA using WINSTEPS Version 4.5.4 software (31). Multi-faceted Rasch analysis was performed by using Facets Version 3.67.1 software (32, 33). To examine the measurement characteristics of CAMSA, a three-step procedure was performed following the CAMSA development guidelines.

First, inter-rater reliability and retest reliability were examined. Inter-rater reliability was evaluated using the multi-faceted Rasch model (MFRM). The MFRM is widely used to examine consistency among multiple raters. Zhu and Cole recommend a fit index infit and outfit (MnSq) criterion between 0.7 and 1.3 for motor skill assessment (34). We referred to Facets guidelines and adopted MnSq values between 0.7 and 1.3 for acceptable criteria in this study (35, 36). The intraclass correlation coefficient (ICC) was used to examine the rater's retest reliability (37). Wikstrom recommends the following criteria for ICC: scores of 0.9–1.0 for excellent; 0.80–0.89 for good; 0.7–0.79 for fair; and below 0.69 for poor (38).

Second, the Rasch residuals were tested for unidimensionality using principal component analysis (PCA). The PCA of the residuals was acceptable when the eigenvalue of the first factor extracted from the residuals was <2.0. Before PCA, the Rasch measurement dimension analysis involved examining point-measurement (PTMEA) biserial correlations and fit statistics (39). The measurement dimensions were confirmed to be devoid of negative PTMEA biserial correlations, and the fit statistics were stable, with no sudden high or low fits.

The difficulty independence assumption was tested using latent parallel analysis (LPA). Once the CAMSA showed a single dominant measurement structure, we performed item-level analyses using the Rasch model. Rasch analysis mainly includes item-fit statistics and differential item functioning (DIF) (37). The two goodness-of-fit statistics were used to examine the fit of the item model, namely infit and outfit (MnSq) (40). In the Rasch model, items are weighted, along with a linear logistic function, in accordance with their level of difficulty. The ratio of observed variance to expected variance will be 1.0 if an item fits this linear function exactly. Mean square values significantly more than 1.0 indicate model underfit, in contrast to values <1.0, which indicate model overfit. Wright and Linuck showed that the acceptable range of MnSq values is between 0.5 and 1.5 (41). Subsequently, some scholars recommend that a standard of MnSq values between 0.6 and 1.4 is better (42–44). Additionally, Bond and Fox argue that MnSq values between 0.7 and 1.3 are more accurate (45). Therefore, MnSq values between 0.7 and 1.3 were used in this study.

In addition, item reliability was assessed in terms of "separation" (G), which was considered to be the ratio of the true distribution of measurements to their measurement error (46). Item separation indices more significant than 2.0 are considered to be good. A related indicator is the reliability of these separation indices, with coefficients ranging from 0 to 1; a coefficient of 0.80 is considered good and 0.90 is considered excellent (46).

TABLE 1 | Demographic characteristics of the participants.

Demographic variables, *n* (%)	Overall	Boys	Girls
Gender	1,094 (100)	545 (49.8)	549 (50.2)
Age, years			
9	271 (24.8)	125 (22.9)	146 (26.6)
10	265 (24.2)	141 (25.9)	124 (22.6)
11	269 (24.6)	137 (25.1)	132 (24.0)
12	289 (26.4)	142 (26.1)	147 (26.8)
BMI			
Normal	893 (81.6)	437 (80.2)	456 (83.1)
Overweight	115 (10.5)	57 (10.5)	58 (10.6)
Obesity	72 (6.6)	41 (7.5)	31 (5.6)
Underweight	14 (1.3)	10 (1.8)	4 (0.7)
Race			
Han Nationality	1,033 (94.4)	505 (92.7)	528 (96.2)
Minorities	61 (5.6)	40 (7.3)	21 (3.8)
Family			
Lived without parents	184 (16.8)	91 (16.7)	92 (16.8)
Lived with one parent	260 (23.8)	134 (24.6)	126 (23.0)
Lived with parents	650 (59.4)	319 (58.5)	331 (60.3)
Urban/Rural			
Urban	660 (60.3)	327 (60.0)	333 (60.7)
Rural	434 (39.7)	218 (40.0)	216 (39.3)

RESULTS

Demographic Characteristics

Table 1 Presents the demographic characteristics of the participants. A total of 49.8% of male and 50.2% of female subjects completed all tests. The BMIs of all subjects showed

TABLE 2 | The results of the inter-rater reliability and retest reliability.

Rater	Model		Infit		Outfit		ICC
	Measure	S.E.	MnSq	ZStd	MnSq	ZStd	
R4	0.08	0.13	1.02	0.4	0.92	−0.3	0.987
R2	0.04	0.13	0.99	−0.2	0.88	−0.6	0.984
R5	0.01	0.13	1.05	0.9	1.29	1.5	0.984
R3	−0.01	0.13	1.00	0	0.89	−0.5	0.979
R6	−0.04	0.13	1.00	0	0.90	−0.5	0.982
R1	−0.08	0.13	0.99	−0.2	0.88	−0.6	0.971

RMSE (model).13, Adj (True) S.D.00, Separation.00, Strata.33, Reliability.00.

TABLE 3 | Item measure and fit statistics.

Item	Model		Infit		Outfit		PTMEASUR-AL	
	Measure	S.E.	MnSq	ZStd	MnSq	ZStd	CORR.	EXP.
CS07	2.73	0.08	1.09	2.16	1.21	3.13	0.27	0.37
CS12	1.14	0.07	1.00	−0.04	1.00	−0.03	0.39	0.38
CS08	1.10	0.07	1.02	1.07	1.01	0.35	0.36	0.38
CS10	0.53	0.07	0.90	−3.64	0.85	−3.72	0.46	0.36
CS09	0.11	0.07	0.92	−2.42	0.95	−0.97	0.41	0.34
CS13	0.06	0.07	1.01	0.26	1.01	0.23	0.32	0.33
CS14	−0.24	0.08	1.05	1.10	1.10	1.35	0.26	0.31
CS04	−0.27	0.08	0.95	−1.08	0.90	−1.46	0.36	0.31
CS11	−0.33	0.08	0.98	−0.48	0.92	−1.05	0.33	0.31
CS03	−0.41	0.08	0.94	−1.13	0.85	−2.03	0.37	0.30
CS05	−0.43	0.08	1.00	0.05	0.96	−0.42	0.30	0.30
CS06	−0.70	0.09	1.03	0.57	1.06	0.65	0.25	0.28
CS01	−0.72	0.09	1.12	1.97	1.34	3.24	0.14	0.28
CS02	−2.56	0.18	1.01	0.13	1.00	0.08	0.13	0.14
Mean	0.00	0.09	1.00	−0.10	1.01	0.00		
P.SD	1.15	0.03	0.06	1.50	0.13	1.80		

that 81.6% were normal, 17.1% were overweight or obese, and 1.3% were underweight. The family status of the subjects showed that 16.8% of the children had lived without their parents for a long time, while only one parent accompanied 23.8% of the participants and both parents accompanied 59.4%. A total of 60.3% of the subjects were from urban areas and 39.7% were from rural areas.

Inter-rater and Retest Reliability

Table 2 presents the results of the inter-rater reliability and retest reliability. The inter-rater reliability results showed that R4 is the strictest and R1 is the loosest. The infit MnSq values of the raters ranged between 0.99 and 1.05, which fit well with the acceptable standard interval of 0.7–1.3. Item separation coefficients of zero and far less than two indicated that inter-rater differences could not be effectively distinguished. In other words, there was no significant variability among raters. The ICC results showed that the retest reliability of the six raters ranged from 0.979 to 0.987, indicating that raters were skilled in the scoring rules.

Rasch Analysis

The results for the measurement dimensions were confirmed to be without negative correlation of PTMEA (r = 0.14–0.46), and the fit statistics were stable (infit MnSq = 0.90–1.12), with no abrupt high or low fit (**Table 3**). The PCA of the residuals indicated that the eigenvalue of the first factor extracted from the residuals was 1.7<2, indicating that the model was consistent with unidimensionality. The correlation between the residuals of the items was not significant (r = 0.01–0.21). Therefore, the local independence assumption was not violated for any item.

The infit and outfit MnSq values for all items were within the standard interval of 0.7–1.3, except for item CS01, which exhibited marginal misfit (outfit MnSq = 1.34). Item CS07 was the most difficult (2.73 logits), while item CS02 was the easiest (−2.56 logits). The results indicated that the item separation index was strong (G = 12.50), being well-above the criterion of 2.0. Item separation reliability was also excellent (r = 0.99).

Figure 2 located both items (difficulty levels) and persons (distribution of person ability) on the same continuum of fundamental movement skill. The figure indicated that the subjects' fundamental movement skill levels ranged from −1.58 to 4.51 logits, and the range of item response difficulty (−2.56 to 2.73 logits) was less than the subjects' fundamental movement skill levels; however, the range of item response difficulty covered 90.7% (n = 991) of the subjects. In addition, only 0.9% (n = 10) of the subjects scored in the highest scoring zone (raw score = 14), and 0.6% (n = 2) scored in the lowest zone (raw score = 3). Thus, there was no significant floor or ceiling effect. Also, **Figure 2** showed that some test items have similar levels of difficulty (e.g., items CS03, CS11, and CS14), but most items target different levels of fundamental motor skill.

The DIF analysis revealed four items falling outside the criteria across the age dimension (**Table 4**). In particular, three items were found between the ages of 11 and 12 (CS06 DIF contrast = −0.62, p = 0.03; CS07 DIF contrast = −0.53, p = 0.01; CS11 DIF contrast = −0.55, p = 0.03) (14). One item was identified between the ages of 10 and 11 (CS01 DIF contrast = −0.59, p = 0.03). The DIF test demonstrated that the four items CS01, CS06, CS07, and CS11, were responded to differently by subjects of different ages (**Table 4**). For the CAMSA, this means that the measurement invariance of the items varies across age groups. In addition, the DIF analysis found that ten items did not fit the criteria across genders, indicating that there were measurable differences in the difficulty of the ten items between genders (**Table 5**).

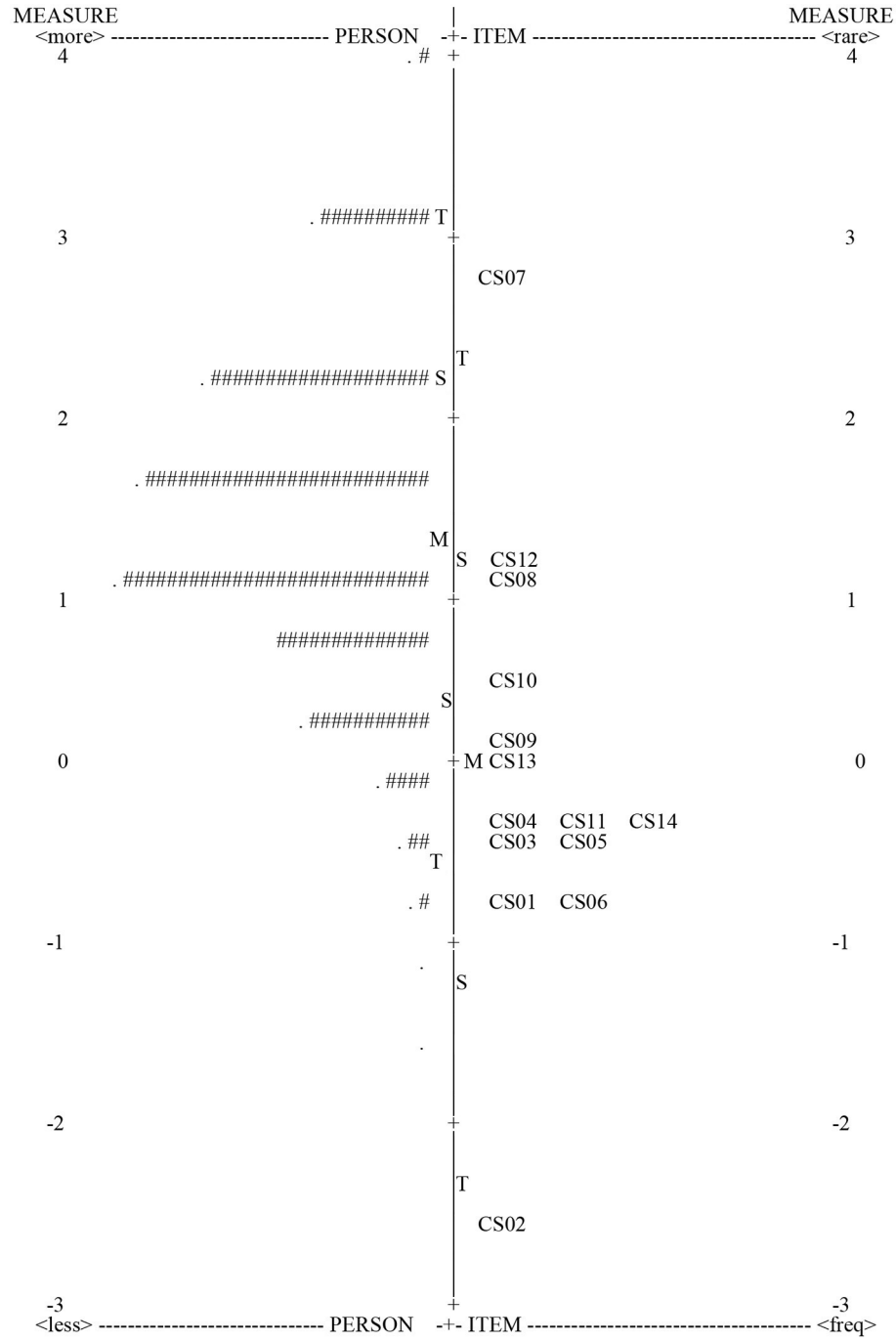

FIGURE 2 | The map of person-item response difficulty locations. Each "#" in the PERSON column is 9 PERSON; each "." is 1 to 8. +M, item mean; M, person mean; S, 1 SD from the mean; T, 2 SD from the mean.

DISCUSSION

The CAMSA is a fundamental movement skills assessment tool for children, but its measurement properties have yet to be thoroughly investigated. The purpose of this study was to investigate the measurement properties of the CAMSA using a Rasch model. This study was the first to use the Rasch model to investigate the CAMSA measurement properties, including item unidimensionality, local independence, item-fit, and differential item functioning (DIF) (47, 48). Overall, the CAMSA displayed adequate inter-rater reliability, retest reliability, internal consistency, and structural validity.

TABLE 4 | Differential item functioning (DIF = Age).

PERSON	DIF	JOINT	Rasch-Welch			Mantel-Haenszel		ITEM
CLASS	CONTRAST	S.E.	*t*	*df*	*Prob.*	Chi-squ	*Prob.*	
9 vs. 10	0.37	0.26	1.42	510	0.16	1.89	0.17	CS01
9 vs. 10	−0.40	0.52	−0.77	528	0.44	0.62	0.43	CS02
9 vs. 10	0.01	0.23	0.06	527	0.95	0.04	0.84	CS03
9 vs. 10	−0.04	0.22	−0.19	528	0.85	0.10	0.76	CS04
9 vs. 10	−0.02	0.22	−0.11	527	0.91	0.00	0.95	CS05
9 vs. 10	0.11	0.24	0.46	523	0.64	0.03	0.86	CS06
9 vs. 10	0.04	0.23	0.17	531	0.86	0.54	0.46	CS07
9 vs. 10	0.13	0.19	0.70	531	0.49	0.39	0.53	CS08
9 vs. 10	−0.13	0.20	−0.63	530	0.53	0.86	0.35	CS09
9 vs. 10	−0.02	0.19	−0.13	530	0.90	0.02	0.89	CS10
9 vs. 10	−0.24	0.22	−1.09	531	0.28	1.33	0.25	CS11
9 vs. 10	0.10	0.19	0.55	531	0.58	0.13	0.72	CS12
9 vs. 10	−0.07	0.20	−0.35	529	0.73	0.00	0.95	CS13
9 vs. 10	−0.09	0.22	−0.40	529	0.69	0.01	0.93	CS14
10 vs. 11	−0.59	0.27	−2.20	518	0.03*	2.58	0.11	CS01
10 vs. 11	−0.11	0.50	−0.22	525	0.83	0.00	1.00	CS02
10 vs. 11	−0.46	0.23	−1.98	523	0.05	4.29	0.04*	CS03
10 vs. 11	−0.32	0.23	−1.40	526	0.16	2.80	0.09	CS04
10 vs. 11	0.02	0.24	0.10	526	0.92	0.01	0.92	CS05
10 vs. 11	0.48	0.28	1.72	506	0.09	2.61	0.11	CS06
10 vs. 11	0.12	0.21	0.54	525	0.59	0.19	0.67	CS07
10 vs. 11	0.21	0.19	1.09	526	0.27	1.26	0.26	CS08
10 vs. 11	−0.05	0.21	−0.25	526	0.80	0.19	0.66	CS09
10 vs. 11	0.21	0.20	1.06	526	0.29	0.71	0.40	CS10
10 vs. 11	0.38	0.24	1.57	517	0.12	1.76	0.18	CS11
10 vs. 11	−0.13	0.19	−0.67	526	0.51	0.12	0.73	CS12
10 vs. 11	0.23	0.22	1.07	524	0.29	0.98	0.32	CS13
10 vs. 11	−0.20	0.22	−0.91	526	0.37	0.47	0.49	CS14
11 vs. 12	0.06	0.26	0.25	546	0.81	0.72	0.40	CS01
11 vs. 12	−0.11	0.53	−0.20	546	0.84	0.04	0.84	CS02
11 vs. 12	0.38	0.24	1.58	541	0.12	2.12	0.15	CS03
11 vs. 12	0.23	0.23	1.01	545	0.31	1.27	0.26	CS04
11 vs. 12	0.07	0.25	0.27	546	0.79	0.01	0.94	CS05
11 vs. 12	−0.62	0.29	−2.16	527	0.03*	2.78	0.10	CS06
11 vs. 12	−0.53	0.21	−2.53	546	0.01*	3.62	0.06	CS07
11 vs. 12	−0.26	0.19	−1.38	543	0.17	1.14	0.28	CS08
11 vs. 12	0.23	0.22	1.05	546	0.30	0.32	0.57	CS09
11 vs. 12	0.27	0.21	1.29	546	0.20	0.24	0.62	CS10
11 vs. 12	−0.55	0.24	−2.24	534	0.03*	5.47	0.02*	CS11
11 vs. 12	0.24	0.19	1.28	545	0.20	0.99	0.32	CS12
11 vs. 12	−0.03	0.23	−0.13	546	0.90	0.01	0.93	CS13
11 vs. 12	0.30	0.24	1.29	544	0.20	1.03	0.31	CS14

*$p < 0.05$.

As expected, a multi-faceted Rasch model to test the consistency of the six raters showed good inter-rater reliability for CAMSA. The rater re-rated after a 1-week interval also demonstrated a positive rater retest reliability. Compared to the retest reliability of rater skills reported by CAMSA developers (ICC = 0.69) (15) and applications in Australia (ICC = 0.85) (2), the rater levels in this study (ICC = 0.979–0.987) were superior to the former. The rater reliability test demonstrated the necessity and validity of the raters' training and provided strong evidence that the CAMSA scoring rules are clear and valid. The establishment of inter-rater reliability and retest reliability assured the quality of CAMSA data collection.

TABLE 5 | Differential item functioning (DIF = gender).

PERSON	DIF	JOINT	Rasch-Welch			Mantel-Haenszel		Size	Item
CLASS	CONTRAST	S.E.	*t*	*d.f.*	*Prob.*	Chi-squ	*Prob.*	CUMLOR	
1 vs. 2	0.41	0.18	2.27	INF	0.02*	2.76	0.10	0.32	CS01
1 vs. 2	0.83	0.39	2.15	INF	0.03*	2.98	0.08	0.74	CS02
1 vs. 2	0.26	0.17	1.55	INF	0.12	3.01	0.08	0.32	CS03
1 vs. 2	0.16	0.16	0.99	INF	0.32	1.32	0.25	0.20	CS04
1 vs. 2	−0.15	0.17	−0.87	INF	0.38	0.71	0.40	−0.16	CS05
1 vs. 2	−0.43	0.18	−2.33	INF	0.02*	4.89	0.03*	−0.42	CS06
1 vs. 2	−0.51	0.16	−3.24	INF	0.00*	10.79	0.00*	−0.51	CS07
1 vs. 2	−1.03	0.14	−7.57	INF	0.00*	54.65	0.00*	−1.00	CS08
1 vs. 2	0.60	0.15	4.01	INF	0.00*	17.67	0.00*	0.68	CS09
1 vs. 2	0.52	0.14	3.77	INF	0.00*	18.10	0.00*	0.65	CS10
1 vs. 2	0.45	0.16	2.77	INF	0.01*	7.66	0.01*	0.47	CS11
1 vs. 2	0.67	0.13	5.08	INF	0.00*	24.27	0.00*	0.68	CS12
1 vs. 2	−0.29	0.15	−1.93	INF	0.05	3.23	0.07	−0.28	CS13
1 vs. 2	−0.90	0.17	−5.37	INF	0.00*	27.70	0.00*	−0.86	CS14

*$p < 0.05$.

Rasch analysis demonstrated that the CAMSA test is unidimensional, with no items violating the local independence assumption, and it is generally a hierarchical and well-developed assessment instrument (46). Analysis of the fit statistics indicated that the items were well-fitted, except for one item (CS01) outside the fitting border in the outfit MnSq. However, some studies suggested that infit values were more stable than outfit values in the item-fit statistics (46). The item CS01 infit MnSq of 1.12 is a trustworthy fit value. Therefore, the overall fit statistics of the CAMSA are regarded as good.

The person-item Wright map (**Figure 2**) shows that item difficulty did not match well with person-ability. With 38.4% of persons between 1 and 2.5 logits, no matching assessment items were found in this interval. In contrast, in the interval of −1 and 0 logits, eight items (57.1%) distinguished only 8.3% of the person-ability. Overall, the test results indicated that the item difficulty of the CAMSA test was low and the person ability was high (49). Therefore, the item difficulty of the CAMSA test struggles to differentiate individual abilities precisely (50). In general, for test results with low item difficulty and high personnel competency, adjusting item difficulty or test sequence is used to calibrate the assessment tool. Since the CAMSA is a closed-ended test instrument, adjusting the action sequence may change the properties of the original test structure. As such, a more appropriate method may be to increase the difficulty of the test items. In particular, in item-intensive locations (−1 to 0 logits), adjusting item difficulty may be a better strategy.

The differential item functioning analysis showed that four items (9.5%) existed DIF by the age factor. However, ten items (71.4%) were significantly DIF by the gender factor. The DIF items that existed by the age factor were mainly between the ages of 11 and 12, while no items between the ages of 9 and 10 years existed significantly in DIF. In terms of the age factor, the number of DIF items was greater in the older group than in the younger group, indicating that the low difficulty of the items may have led to a decrease in the differentiation of the older group, and thus to the DIF. Furthermore, the DIF was present in 71.4% of the items in the gender factor. The difference in movement test results across genders is inevitable in terms of physical and physiological interpretation. However, this also suggests that we should be cautious in interpreting differences between genders when using CAMSA test results.

First, although the validity of the CAMSA skills test fitting was good, poor matching of personal ability to item difficulty may result in differences in CAMSA discrimination. Second, the differential item functioning across genders prompted us to be cautious about comparing the results between men and women. Third, although the CAMSA is a well-tested assessment of "real sport" motor skills, there are still many agility motor skills (e.g., bilateral coordination, dynamic balance) that may not be assessed. Therefore, we need to improve the validity of the CAMSA measurements by increasing movement difficulty, adjusting movement scoring criteria, and enhancing the match between the difficulty of the instrument's movements and personal ability. This is a task for future studies. Furthermore, we recommend and encourage researchers and elementary physical education teachers to use the CAMSA to replace the traditional assessment tool of fundamental movement skills.

CONCLUSIONS

The present study is the first to analyze the measurement properties of the CAMSA using the Rasch model. The CAMSA, as a closed-loop measure of fundamental movement skills in children, demonstrated good unidimensionality, local assumption independence, and item-fit statistics. The inter-rater reliability and retest reliability revealed

that the CAMSA was internally consistent. However, there were significant differences in its person–item fit matching and across genders in relation to differential item functioning.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Scientific and Ethics Committee of Institute of Motor Quotient, Southwest University (IRB NO. SWUIMQ20190605). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JC and LY: data collection. JC and HY: data analysis. JC, JW, and NS: conception and design. JC, LY, HY, and JW: writing the manuscript and revision. All authors contributed to the article and approved the submitted version.

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The Fitness Barometer: A Best Practice Example for Monitoring Motor Performance With Pooled Data Collected From Practitioners

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Introduction: Motor Performance (MP) in children is an important resource for their future active lifestyle and health. Monitoring of MP is crucial to derive information of trends and to implement specific programs on the base of current MP levels. A variety of MP assessment tools exist, making it difficult to determine a "gold-standard" for assessment and to compare the findings. In Germany, the German Motor Test 6–18 (GMT 6–18) and Kinderturntest Plus 3–10 (KITT+ 3–10) are widely used MP assessment tools. The aim of this paper is to show which key questions can be answered within the context of a best practice example of a MP assessment tool and what can be derived from this for a practical application (the Fitness Barometer).

Methods: The raw data of the Fitness Barometer was collected with the MP assessment tools GMT 6–18 and KITT+ 3–10 from 2012 through 2020. Data was pooled anonymously with the e-Research infrastructure MO|REdata and categorized into percentiles for MP and BMI. Overall, we included data of 23,864 children for the statistical analyses. *T*-tests for independent samples, percentage frequency analysis, descriptive statistics (chi- square-test) and single analysis of variance were conducted.

Results and Discussion: Children tested reached a mean value of 57.03 ($SD = 18.85$). Of the sample, 12.7% children were overweight or obese and there is a significant difference between age groups [$\chi^2_{(4)} = 178.62$, $p < 0.001$, Cramer $V = 0.09$; $n = 23.656$]. The relationship between BMI category and mean value of MP was significant [$F_{(4,19,523)} = 224.81$, $p < 0.001$]. During 2020, the year of the COVID-19 pandemic, mean value of endurance and speed decreased [Welch's $F_{(1,573)} = 8.08$, $p = 0.005$; Welch's $F_{(1,610)} = 35.92$, $p < 0.001$]. The GMT 6–18 and KITT+ 3–10 are valid, objective, reliable, and economic MP assessment tools for monitoring MP levels and derive added practical value. Specific programs and interventions should focus on the findings of these. The Fitness Barometer is a best practice example how a standardized assessment tool of monitoring MP point to trends on which practical evidence-based suggestions can be derived with many various partners and expertise.

Keywords: assessment, monitoring, physical fitness, youth, children

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INTRODUCTION

Systematic monitoring is used in many areas of life to document trends and changes in society and to describe their course over a certain period. For example, a popular monitoring instrument for examining school capacity is the international PISA study (1). The results provoked changes and adjustments in national education plans and policy, and the implementation of specific programs and interventions.

Similarly, identifying the current level of Motor Performance (MP) is crucial to plan, design, and evaluate adequate interventions and programs to maintain and increase physical activity in youth[1].

MP is one of the main resources for an active lifestyle and therefore of great significance for healthy development in childhood, adolescence, and throughout one's entire lifespan (5–9). The development of MP either encourages or discourages an individual to engage in physical activity through limiting one's opportunities (7, 10–12). With increasing MP, the risk of overweight decreases and maximal oxygen intake in childhood is improved (10, 13). A positive association has been found for cardiorespiratory and muscular fitness (14). Moreover, well-developed MP is related to a lower risk for current and future diseases, and has a positive effect on the physical self- concept development of personality and cognitive abilities (15–18).

Systematic monitoring requires validated, objective, and reliable tools.

There are numerous tools for assessing MP in children and adolescents, and also many theories behind them. However, there is no "gold-standard" through research and the challenge is to bring together various interests (19–21). With quantitative assessment tools, MP levels are measured according to outcome and the results are compared with those of a norm group. In contrast, qualitative assessment tools focus more on how the specific task and its components are performed (22, 23). Additionally, the characteristics and circumstances of the target group, meaning geographical region, socio-economical background, and culture of the participants, determine which assessment tool is preferred (19, 20).

Another challenge of assessing MP is the different purposes of practice and research with the common aim of monitoring MP in children and adolescents and making statements about trends and development. MP assessment tools should meet the general research criteria of objectivity, reliability, and validity. For practitioners, using MP assessment tools and interpreting their results should be simple and easy, and the implementation should be feasible for the specific setting (24).

Comparable monitoring of MP to assess the complex construct as a central component of physical development should be implemented considering its high importance for health. A common and widely accepted MP monitoring tool would allow a pooling of data from different studies, and the lack of nationally and internationally representative samples could be addressed. This would open new insights and possibilities of comparing MP globally and over several decades (15). In addition, it is necessary to establish age and gender-adjusted reference values, and to provide normative criterion values of adequate health-influencing MP for standardized national and international monitoring (19, 25).

In Germany, the German Motor Test 6–18 (GMT 6–18) (26) and the adjusted Kinderturntest Plus 3–10 (KITT+ 3–10) (27) are widely used MP assessment tools.

In this paper, we aim to demonstrate the best practice example for a valid, objective, reliable, and economic MP tool, which targets monitoring MP levels and gives added practical value (the Fitness Barometer). The collection of data by practitioners in the direct setting of physical activity of children and adolescents establishes a collaborative relationship from which researcher, as well as the testing educators, teachers, trainers, and coaches, can extract the optimal benefits. The enormous amount of resources normally required for a long-term continuous cohort study is thus reduced, making the approach of monitoring much easier.

We show examples of which key questions can be answered within the context of the Fitness Barometer and what can be derived from these answers for practical application.

These are:

1. What is the mean value of MP in children aged 3–10 years in the German federal state of Baden-Württemberg?
2. What is the mean BMI in children aged 3–10 years in the German federal state of Baden-Württemberg?
3. Are there differences in MP in children aged 3–10 years in the German federal state of Baden-Württemberg depending on BMI?
4. Is there an influence of the COVID-19 pandemic on the MP in children aged 3–10 years in the German federal state of Baden-Württemberg?

MATERIALS AND METHODS

The GMT 6–18 and KITT+ 3–10

The raw data of the Fitness Barometer was collected with the MP assessment tools GMT 6–18 and KITT+ 3–10. These are effective and economical MP assessment tools developed to be conducted in practical settings. The GMT 6–18 is based on the approach of Bös and Mechling (28) and KITT+ 3–10 is an adjustment for younger children. It contains eight test items representing the five main dimensions of MP endurance, strength, speed, coordination, and flexibility. Additionally, constitutional data including height, weight, and BMI were collected, and children's age and sex, as well as test date and other characteristics of data collection were recorded (28). **Table 1** shows the different test items in the main dimensions.

Data Collection Using GMT 6–18 and KITT+ 3–10

From 2012 to 2020, the test tools GMT 6–18 and KITT+ 3–10 were used to test MP in Germany, with a main emphasis on one

[1]There are several different terms, definitions, and notions of the complex and multi-dimensional construct of children's motor performance (MP). In this paper, we use MP as the general level of someone's ability to utilize motor skills, fundamental movement skills, and motor competence. With an increasing level of MP, the essential fundamental competence and knowledge to be physically active is given (2–4).

TABLE 1 | Test items of the GMT 6–18 and KITT+ 3–10.

Dimension	Test item
Endurance	6-min run
Strength	Standing long jump
	Sit-ups
	Push-ups
Speed	20-m dash
Coordination	Balancing backwards
	Jumping sideways
Flexibility	Stand and reach

federal state (Baden-Wuerttemberg). The Fitness Barometer is a project in cooperation with the Kinderturnstiftung of Baden-Württemberg and therefore drawing of the sample is limited through structural reasons on this federal state of Germany. However, Baden-Württemberg is the third largest federal state in Germany and has 704,725 children in our analyzed age-group (29). For the future an extension of the project all over Germany is planned.

The relevant target group of kindergartens, schools, and sports clubs were informed via newsletter and informational material from the ministry of education. They were invited to participate and collect data with the KITT+ 3–10 and GMT 6–18.

The implementation of the test tools is easy to conduct and can be integrated into regular physical activity sessions. Teachers, educators, trainers, and coaches were trained as multipliers and, with the help of material and additional scientific support, enabled to conduct the tests with their groups. They entered data into an evaluation software which calculates results for the subjects and group-based profiles compared with norm values (26, 27).

The raw data of the children's MP was anonymized and pooled after a quality check using the e-Research infrastructure MO|REdata (Karlsruhe Institute of Technology, Karlsruhe, Germany). To analyze the data from communities/regional councils in Baden-Wuerttemberg, only data which could be allocated to the federal state through postal code were extracted from the pooled overall data set and analyzed with IBM SPSS Statistics 27.

The first pooling in MO|REdata was conducted with the data base of raw data from 2012 until 2018, and analyzed in the first publication of "the Fitness Barometer" (30). Subsequently, this data base was extended using the actual raw data of the previous year. Therefore, this paper comprises data, collected by practitioners from 2012 until the end of 2020.

Sample Description

The sample comprises data from children between the ages of 3 and 10. Most data derive from investigations using KITT+ 3–10 and were supplemented with age-specific data from the GMT 6–18 through data pooling. In the strict sense and with statistical objectivity the sample does not meet representativity. However, the analysis of the communities/regional councils in which the GMT 6–18 and KITT+ 3–10 were implemented shows a comprehensive distribution.

From 2012 through 2019, data from 22,930 children [MV ± SD: age: 6.68 ± 1.75; weight: 25.9 ± 7.3 kg; height: 124.7 ± 12.2 cm] from schools, kindergartens, and sports clubs were included in the analysis. Among them, 51% (n = 11,654) were boys and 49% (n = 11,276) were girls. The distribution of age groups was 28% (n = 6,511) 3–5 years old (kindergarten age) and 72% (n = 16,419) 6–10 years old (elementary school age).

During 2020, testing was difficult due to the COVID-19 pandemic conditions. Therefore, data was only collected from 934 children [MV ± SD: age: 6.75 ± 1.89; weight: 25.8 ± 7.8 kg; height: 125.2 ± 13.0 cm]. The distribution of gender was equal, and 32% (n = 303) were aged 3–5 years and 68% (n = 631) were aged 6–10 years. This latest data was pooled with the data from 2012 through 2019.

Overall, the data included in the statistical analysis of this study covers a time frame of 9 years (2012–2020), and the total number of children was 23,864 [MV ± SD: age: 6.6 ± 1.76; weight: 25.9 ± 7.3 kg; height: 124.7 ± 12.3 cm]. Among them, 51% (n = 12,123) were boys and 49% (n = 11,741) were girls. The different age groups comprised 29% ages 3–5 (n = 6,814) and 71% ages 6–10 (n = 17,050). **Table 2** shows the gender-specific samples of the different investigation periods.

Statistical Analysis

Statistical analyses were conducted with IBM SPSS Statistics 27. The pooled data set includes the data from the investigations conducted from 2012 through 2020. For a specific analysis of the effects and consequences of the COVID-19 pandemic, the results of the investigation period from 2012 through 2019 were compared with those from 2020.

To analyze the current levels of MP and BMI (Questions 1 and 2) compared to the nationwide reference sample, data was classified into reference percentiles, and we examine age and gender-specific relationships. A sum score describing the overall MP level was calculated from the percentile results of the test items. This sum score was only calculated if all four (age range from 3 to 5) or all eight (age range from 6 to 10) test items were completed. The representative percentile curves for Germany were used for the six test items stand-and-reach, push-up, sit-up, standing long jump, jumping sideways, and balancing backwards (31). For 20-m dash and 6-min run percentile curves were created based on the raw data of the overall data set with the data sets KITT+ 3–10 and GMT 6–18 (32). Data were differentiated by age and gender, and differences were examined with t- tests for independent samples and descriptive statistics after results were placed in reference percentiles. Level of significance was set at $p < 0.05$. The standardized effect size was calculated using Cohen's d, classifying small (0.20), medium (0.50), and large (0.80) effects (33).

BMI was calculated from individual weight and height and classified into percentiles of BMI and categorized according to the percentile groups described by Kromeyer-Hauschild (34). As we are conducting a nationwide comparison of German children, we used reference percentiles for Germany. Age and gender-specific differences were examined based on percentage

TABLE 2 | Sample description (means ± SD).

	2012–2019		2020		2012–2020	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
N	11,654 (51%)	11,276 (49%)	469 (50%)	465 (50%)	12,123 (51%)	11,741 (49%)
Age	6.7 ± 1.8	6.7 ± 1.8	6.9 ± 1.9	6.6 ± 1.9	6.7 ± 1.8	6.7 ±1.8
Weight	26.2 ± 7.4 kg	25.5 ± 7.2 kg	26.4 ± 8.0 kg	25.1 ± 7.6 kg	26.3 ± 7.4 kg	25.5 ± 7.3 kg
Height	125.5 ± 12.2 cm	123.8 ± 12.2 cm	126.4 ± 13.2 cm	123.9 ± 12.8 cm	125.5 ± 12.2 cm	123.8 ± 12.3 cm

frequency analysis and descriptive statistics (chi- square-test). Level of significance was set at $p < 0.05$. Cramer's V was used to state the power of relation and categorized into small (0.10), medium (0.30), and large (0.50) effects (33).

The relationship between fitness sum score and BMI and the short-term effects and consequences of the COVID-19 pandemic on MP (Questions 3 and 4) were examined using single analysis of variance. Effect sizes were assessed with omega square (ω^2) due to lower bias. Limits of effect sizes were 0.01 (small effect), 0.06 (medium effect), and 0.14 (large effect) (33). In consequence of homogeneity of variance, the Hochberg correction was applied for *post-hoc* multiple comparisons. The Welch test was used when homogeneity of variance was not given and the Games- Howell correction was used as *post-hoc* test. Level of significance was set at $p < 0.05$. Confidence intervals were also stated. The additional information of effect sizes and confidence intervals of the mean values were stated in order to be able to assess the relevance of the differences more objectively. With our sample size of more than 20,000 participants, even small differences in the mean values result in significance.

RESULTS

Motor Performance in Tested Children (Question 1)

Of the 23,864 children tested, $n = 19{,}655$ (= 82.4%) completed all test items in their age group and as a consequence was computed the sum score of MP. Overall, the children reached a mean value of 57.03 ($SD = 18.85$). The nationwide reference value is 50 (mean); this implies that MP of the sample from Baden-Wuerttemberg was 7% better compared to the national average for Germany (31).

The comparison of gender specific differences showed that boys (mean = 58.60, $SD = 18.59$) scored three percentile ranks better than girls (mean = 55.43, $SD = 18.98$), but the effect size revealed small practical relevance [$t_{(19,653)} = 11.86$, $p < 0.001$, $d = 0.20$].

The level of MP did not differ significantly between the specific age groups: kindergarten age (mean = 56.87, $SD = 21.23$) and elementary school age [mean = 57.09, $SD = 17.85$, $t_{(8,599)} = -0.68$, $p = 0.499$].

BMI in Tested Children (Question 2)

BMI-categorization according to Kromeyer-Hauschild (34) was carried out for $n = 23{,}656$ (99.1%), and classified 12.7% ($n = 2{,}990$) of the tested children as overweight or obese. This 12.7% could be divided into 5.2% ($n = 1{,}225$) obese and 7.5% ($n = 1{,}765$) overweight children. 79.2% ($n = 18{,}725$) children were normal weight, and 8.2% ($n = 1{,}941$) were underweight.

Chi-square tests analyzing the relationship between BMI category and gender across the general sample were significant but with no relevant differences [$\chi^2_{(4)} = 19.25$, $p = 0.001$, Cramer $V = 0.03$; $n = 23{,}656$]. However, the boys in the sample were 0.6% more overweight than the girls (boys: 12.9% $n = 1{,}555$; girls: 12.3% $n = 1{,}435$).

Comparing age group-specific differences, overweight increased from 8.3% at kindergarten age (3- to 5-year-olds, $n = 557$) to 14.4% at elementary school age (6- to 10-year-olds, $n = 2{,}433$). The percentage of obese children in the sample doubled from 3.0% (kindergarten age) to 6.1% (elementary school age). Underweight was nearly the same in both age groups, but normal weight decreased from 83.8% (3- to 5-year-olds, $n = 5{,}675$) to 77.3% (6- to 10-year-olds, $n = 13{,}050$). Chi-square-tests reveal significance between BMI category and age group with a small effect [$\chi^2_{(4)} = 178.62$, $p < 0.001$, Cramer $V = 0.09$; $n = 23.656$]. **Figure 1** illustrates the percentage distribution of overweight and obese within BMI category between age groups.

Relationship Between MP and BMI in Tested Children (Question 3)

The relationship between BMI categories and mean value of MP was examined for 81.8% ($n = 19{,}528$) of the children tested.

There was a significant relationship between BMI category and mean value of MP [$F_{(4,19,523)} = 224.81$, $p < 0.001$] with small effect size $\omega^2 = 0.04$. Normal weight children achieved the highest fitness percentile values.

The *post-hoc* analysis revealed that fitness sum score of the BMI category obese was significantly different ($p < 0.001$) from all other categories.

Obese children scored 16 percentile ranks lower (−16.04, 95% CI [−17.74, −14.35]) than normal-weight children in the tested sample and 7.8 percentile ranks lower than overweight children (−7.80, 95% CI [−9.92, −5.67]). Anyway, overweight children had a significantly lower fitness sum score than normal weight children (−8.25, 95% CI [−9.65, −6.85]). **Table 3** shows the mean values of MP in the different BMI categories.

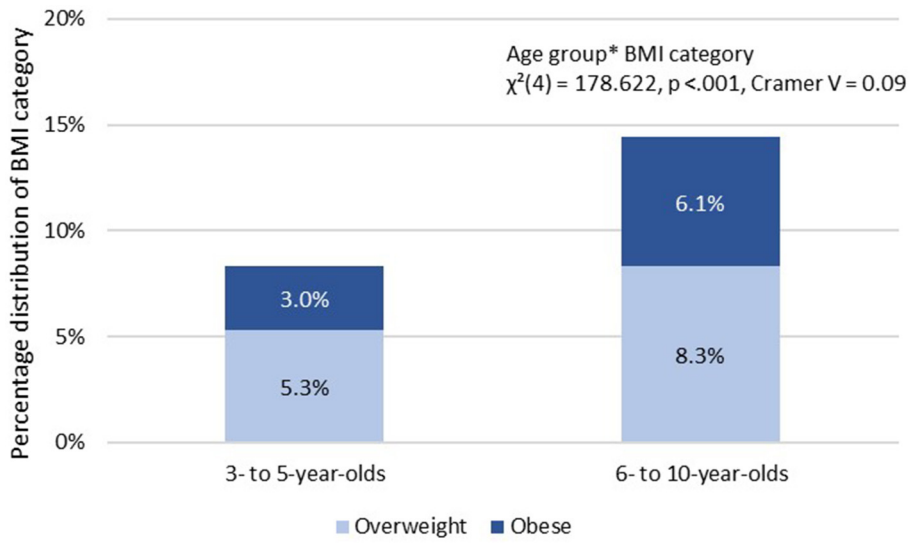

FIGURE 1 | Percentage distribution of overweight and obese within BMI category overweight between age groups.

TABLE 3 | Mean value of MP in the different BMI categories.

	BMI category				
	≤3	>3–10	>10–90	>90–97	>97
N	494	1,087	15,542	1,448	957
Mean value of MP (95% CI)	55.44 (53.82–57.05)	57.75 (56.64–58.87)	58.48 (58.19–58.77)	50.23 (49.30–51.17)	42.44 (41.30–43.58)
			$[F_{(4,19,523)} = 224.81, p < 0.001, \omega^2 = 0.04]$		

Motor Performance and the COVID-19 Pandemic (Question 4)

In 2020, $n = 934$ children were tested. Of these, 79.3% ($n = 741$) completed all test items in their age group and a sum score of MP was conducted. The children tested in the period from 2012 through 2019 reached a mean value of 56.95 ($SD = 18.84$, $n = 18{,}914$) and those tested in 2020 reached a mean value of 59.17 ($SD = 19.07$, $n = 741$).

Comparing the mean values of the main dimensions between the period from 2012 through 2019 and 2020, there was a significant decrease of 3.7 percentile ranks for endurance [2012–2019: mean = 49.96, $SD = 28.13$, $n = 15.337$; 2020: mean = 46.27, $SD = 29.79$, $n = 540$; Welch's $F_{(1,573)} = 8.08$, $p = 0.005$]. Similarly, for speed, the percentile rank decreased from mean of 49.79 for 2012–2019 ($SD = 28.73$, $n = 15{,}526$) to mean of 42.80 in 2020 ($SD = 27.13$, $n = 564$) and the difference was significant [Welch's $F_{(1,610)} = 35.92$, $p < 0.001$]. However, the effect sizes did not measure practical relevance.

The percentile rank of strength, representing the test items standing long jump, sit-ups, and push-ups, increased significantly in 2020 (mean = 61.80, $SD = 27.52$, $n = 825$) compared to the period from 2012 to 2019 [mean = 56.11, $SD = 26.48$, $n = 20{,}950$; ANOVA $F_{(1,21,773)} = 36.44$, $p < 0.001$]. There was also a 2.5 percentile rank increase in the flexibility percentile [2012–2019: mean = 50.60, $SD = 31.57$, $n = 21{,}140$; 2020: mean = 53.06, $SD = 30.12$, $n = 884$; Welch's $F_{(1,966)} = 5.62$, $p = 0.018$], but without practical relevance.

There was no statistically significant difference between the coordination percentile from 2012 to 2019 (mean = 63.98, $SD = 31.57$, $n = 21{,}140$) compared to the coordination percentile in 2020 [mean = 62.92, $SD = 26.00$, $n = 856$; ANOVA $F_{(1,22,014)} = 1.461$, $p = 0.227$]. **Figure 2** shows the mean values of MP for the five dimensions according to field testing period.

DISCUSSION

The aim of this paper was to demonstrate a concrete best practice example of a valid, objective, reliable, and economical MP tool (the Fitness Barometer) that is implemented in practice and provides benefits to practitioners and researchers. Furthermore, we show which relevant key questions can be answered in the context of the Fitness Barometer and which consequences can be derived from this for practical implementation.

The analysis of MP in children tested in one federal state of Germany (Question 1) revealed that they were fitter compared to the national reference group and that boys scored at a higher percentile than girls. With a mean value of 57.03, the MP

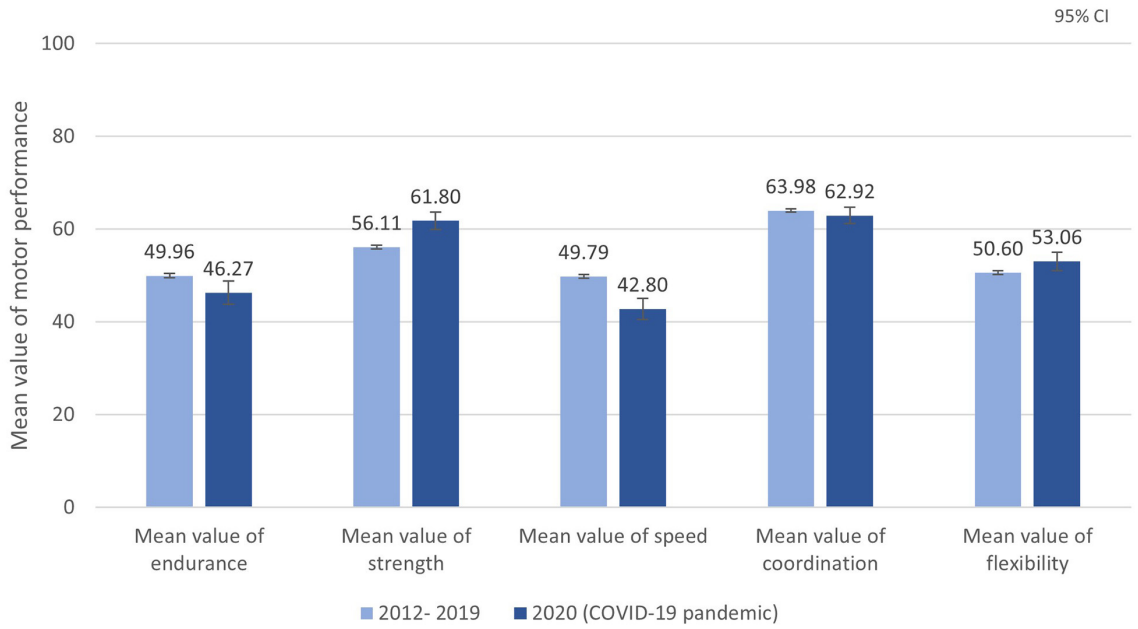

FIGURE 2 | Mean values of MP for the five dimensions according to field testing period.

is average and matches results of the MoMo study, which is representative for Germany (31).

In our sample, one-eighth of the children tested were overweight or obese (Question 2). Cross-sectional results from the KIGGS-study for the period 2014–2017 show a prevalence of overweight and obesity of 15.4% for ages 3–17 years (35). They also found evidence for an increase in both overweight and obesity with increasing age, confirming our findings that the proportion of obesity doubles between kindergarten and elementary school. This significant prevalence is even more dramatic when one recognizes that this period is a fundamental and predeterminate for the future development of MP (3, 10, 36, 37). Therefore, interventions and programs should target this transition and the specific changes that occur in the daily routines of children's lives. For example, schools and institutions should establish movement breaks in the classroom and create an environment and infrastructure which invites to move and to be physical active.

The detected relationship between MP and BMI category (Question 3) shows the significance of specific support for overweight children. With the present finding and several evidence that they have poorer MP compared to normal weight children, it is crucial to break the cycle. There are subsequently more consequences and causalities of overweight and obesity leading to an inactive lifestyle (13, 14, 37). The immediate practical suggestion is to create situations giving overweight children the possibility of using their body mass positively and experience motivation and enhancement.

The main findings of the analyses of the impact of the COVID-19 pandemic on MP (Question 4) pointed out to the relevant role of physical activity with peers and within an institution (38). While the percentiles in the dimensions strength and coordination increased and flexibility remained stable, endurance, and speed percentiles decreased significantly. Even though these are only short-term tendencies and long-term effects must be examined in further analyses, it seems that some alternative options like online and indoor workouts for children may mitigate some dimensions during the COVID-19 pandemic, but not when running and sprinting are essential. The results of an investigation within the MoMo study showed that daily activity increased during the lockdown, but physical activity still decreased (38). It strengthens the role of physical activity in an organized form and setting like sports clubs, schools, or in kindergartens. Intensity is higher and the quality of movement is better through trained and qualified coaches. For future comparable situations of massive restrictions, opportunities and concepts of possible adequate activity and MP should be developed to mitigate the effects of missing organized sports and physical activity for everyone and to build awareness of the consequences of insufficient physical activity (39). It will be interesting to investigate the long-term effects and influence of the COVID-19 pandemic in so-called "Corona- age groups" and makes the monitoring of MP even more necessary. With the investigation period of the Fitness Barometer since 2012 we have cohort data before and after the COVID-19 pandemic and therefore an innovative and rare possibility of comparison.

The constituted results of the statistical analysis give an overview of the aspects of monitoring MP within the Fitness Barometer. First, it points out the current and latest state of MP in children and adolescents continuously. Second, changes and trends were identified, and finally with regard to the large sample displaying the relevant age-group, policy, and decision-maker are influenced and suggested to initiate specific and differentiated concepts of promotion of MP in children and adolescents.

As requested by Lopes et al. (19), the Fitness Barometer fulfills the requirement of a multidisciplinary approach in many ways. The special aspect of data collection with the GMT 6–18 and KITT+ 3–10 through practitioners guarantees a field-based assessment in various settings. That is why, large sample sizes within different age groups and cultural contexts are possible. Test items are fundamental tasks which make the latent construct of MP measurable. Standardization is necessary for national and international comparability. To ensure standardization, there is a detailed manual with precise descriptions and additional information on the homepage (www.turnbeutelbande.de). In addition, multipliers were trained by experts and a service hotline was set up. An English version of the GMT 6–18 manual is in progress and will be published soon under the name IPPTP-R (40).

The research confirms objectivity and standardization of the test items with no problems regarding test implementation. Test-retest reliability is satisfactory but reveals the difficulties in measuring coordinative abilities. Precise instructions and explanations are essential, and instructions for administering the test should be adhered strictly to ensure high reliability (26). Overall, the analysis of construct validity confirms the quality of the theoretical framework based on the GMT 6–18 and the assumption of dimensionality of motor performance (41). In particular, with an investigation of expert ratings and their assessment of good practicability of the GMT 6–18, the challenge of serving research and practice mentioned by Lopes et al. (19) is overcome. The test tool meets the research criteria and yet is economical and efficient in its implementation.

With many small samples from a large number of testing events in kindergartens, schools, and sports clubs, pooling data allows MP development to be monitored based on a large data base. For the Fitness Barometer, we use the MO|REdata e-research infrastructure and ensure the inclusion of all available data (www.motor-research-data.org). The collaborative repository for MP data was developed to store, combine, and evaluate data. It provides a global and robust overview of specific test items to state a comprehensive prevalence and monitoring of trends over time (42).

The Fitness Barometer with its base of pooled data gives an example of a feasible monitoring system. The widespread test tools (GMT 6–18 and KITT+ 3–10) guarantee a consistent and standardized investigation and collection of data. Regular and consistent monitoring with standardized methods should be implemented into the life of educational institutions at the national level by decision-makers and in policy (19).

This integration of relevant stakeholders provides awareness and acceptance by influencing networks and is essential for evidence that leads to practical implementation and programs targeting children's MP (19). The Fitness Barometer is a cooperation between many partners within their specific expertise and perspectives, e.g., sports clubs, sports associations, health promotion foundations, health insurance companies. The common aim is to increase the awareness about the importance of health-related physical activity in childhood. With the Fitness Barometer, practical recommendations, and guidelines based on evidenced monitoring data of MP were published annually to effectively promote physical activity. This fulfills the need to translate research into practice. For example, the data and findings of the Fitness Barometer collection could be reused for political initiatives and reports for the general public like the global alliance of "active healthy kids," an initiative which develops report cards on physical activity of youth in different countries (43).

CONCLUSION

Given the known benefits of high MP levels for active lifestyles and health, the importance of promoting physical activity in childhood and adolescence becomes clear. To adjust and assess programs, interventions, and initiatives, consistent scientific monitoring with findings from standardized assessment tools is the basis on which adequate measures should be built. Public awareness and a common effort to promote the need for physical activity, especially in this stage of life, is the main factor for effective implementation. The Fitness Barometer is a best practice example for monitoring MP with pooled data collected from practitioners.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: http://motor-research-data.org/.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Karlsruhe Institute of Technology. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

TE drafted the initial manuscript, did the statistical analysis, and revised the manuscript. CN contributed particularly to the Introduction and Discussion sections. CN and KB reviewed the manuscript and lead the project. All authors have read and agreed to the published version of the manuscript.

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The Feasibility and Challenges of Conducting Online Research to Examine Movement Behavior in Parents and Children During the COVID-19 Pandemic

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The global pandemic of COVID-19 shifted the methodology of this research project. The purpose of this perspective article is to discuss the feasibility and challenges of converting an in-person mixed methods study that examined associations among and beliefs about physical activity, motor competence, and perceived competence to an online format with parents and children during the COVID-19 pandemic. Recruitment was conducted through a University research registry, social media, and public listservs. All correspondence with participants was through email and secure platforms. Physical activity was assessed with accelerometers mailed to participants. Motor competence was assessed through participant-filmed trials of motor skills. Perceived competence was assessed with the Self-Perception Profile for Adults and Children delivered on Qualtrics. Semi- structured interviews to examine beliefs were conducted over Zoom. Approximately 200 families expressed interest in the study, 76 parent-child dyads consented and assented, and 61 parent-child dyads completed at least one component of the study. It is feasible to conduct online research that contributes to scientific knowledge and has potential advantages. However, various challenges need to be considered regarding the application of online research. These challenges included recruitment, the data collection process, and data quality. Future research needs to address these challenges by utilizing wide-reaching and diverse recruitment methods, easing participants' burden with technology, and developing motor competence and perceived competence assessments that can be administered online. The way research was conducted changed due to COVID-19 and adapting to and/or integrating online methods is both necessary and feasible, but modifications must be taken into consideration.

Keywords: physical activity, motor competence, perceived competence, COVID-19, online research

INTRODUCTION

Physical activity is an effective way to promote overall health. It is well-established that there is a positive and favorable association between physical activity and numerous health indicators in children and adults (1, 2). Despite these direct health benefits, both children's and adult's physical activity levels are extremely low in the United States (3, 4). A potential contributing factor to low physical activity is low motor competence and perceived competence (5, 6). Motor competence is one's proficiency in a wide range of gross motor skills, including fundamental motor skills (FMS; i.e., locomotor and ball skills) (5). FMS are basic learned movement patterns or "building blocks" that do not occur naturally and are foundational to more complex movements, sports, and physical activities (7). Motor competence has been associated with physical activity in children (8–10) and adolescents (11–14). However, in adults, there is limited research examining motor competence, including FMS. Thus, the association with physical activity is not fully understood (15–18). Perceived competence refers to one's self-perception of their abilities (5, 6, 19). In children, perceived competence is significantly associated with motor competence (20–22) and physical activity (20, 21, 23), and has been found to mediate the association between motor competence and physical activity (11, 24, 25). In adults, perceived competence is significantly associated with actual motor competence (16, 17) and physical activity (17). Based on the literature, it is probable that low motor competence and perceived competence in children could be contributing to low levels of physical activity in adults. Still, to date, the research in this area is scarce.

Parents play an integral role in influencing health behaviors in their children, as they have the most contact hours in and control of their child's lives (26, 27). Research has shown that parents' physical activity is a significant predictor of their children's physical activity (26–30). However, to the authors' knowledge, no published research has investigated the association of motor competence between parent-child dyads. Lastly, few qualitative studies examine beliefs about physical activity (31–35), and none examining beliefs about motor competence. Exploring the associations of and beliefs about physical activity, motor competence, and perceived competence in parents and children was warranted.

The global pandemic of Coronavirus disease 2019 (COVID-19) and Executive Orders instituted across the United States (US) dramatically altered how we live, learn, and conduct research. The need to pivot from in-person to online research was essential and instantaneous (36, 37). Research using converted methodologies demonstrated feasibility, highlighted challenges, and provided recommendations (36). It is critical to examine methodologies across different fields to ensure high-quality research was conducted during COVID-19 and provide implications for future research (37). However, online research in motor development is unexplored. To the authors' knowledge, no studies had attempted to use online methodologies to assess motor skills nor perceived competence with parents and children before COVID-19. Conducting motor development research online faces unique challenges due to assessment feasibility and administration concerns. We used rapid-cycle evaluation (RCE) to convert an in-person mixed methods study to online.

The RCE approach entails identifying acute research problems and addressing them using contextually-appropriate methods (38). The phases of RCE are *preparation*, *problem exploration*, *knowledge exploration*, *solution development*, *solution testing*, and *implementation and dissemination* (38). For the *preparation* stage, the authors, experts in Kinesiology and Public Health, sought to identify the best way to alter this study while holding true to the original research questions and methods. The purpose of this perspective article was two-fold. First, we discussed the methods of adaptation (*problem exploration-solution development)* from in-person to online. Second, we discussed the feasibility/results *(solution testing)* and challenges/discussion of recruitment, data collection, and data quality of the converted online study that examined physical activity, motor competence, and perceived motor competence in parents and children.

It is important to examine and evaluate online research methodologies in motor development because we believe that as we emerge from COVID-19 motor development research will continue to be conducted online due to accessibility, potential research restrictions, and/or participants' apprehension of in-person research. The unprecedented times of COVID-19 provided a unique opportunity for online research to help advance the science and application of motor development research that will further advance the field.

METHODS

Following the RCE stages, the investigators adapted the original study using *problem exploration* and *knowledge exploration* (38). We had to identify the key problems and best solutions to convert an in-person study. In terms of recruitment, originally it was limited to local elementary schools. To adapt, the research team elected to recruit participants online through online social media (i.e., Facebook, Twitter, and Instagram), public listservs, and the University Research Registry for parent-child dyads. Inclusion criteria for children were children of all genders aged 8–11 years old, developmental ability to complete physical tasks, speak and understand English. Inclusion criteria for parents/legal guardians were: child's primary caregiver, ability to complete physical tasks, complete questionnaires, and speak and understand English. Participants had to be residents of Michigan and have access to filming devices and the internet. The decision to only include Michigan residents was due to individuals having more similar COVID-19 experiences since each state across the US had varying regulations and COVID-19 guidelines. Data collection took place from July-October 2020. All correspondence with participants took place through email and transfer of files (i.e., consents, assents, and data forms) was done through Box (Redwood City, CA) and Dropbox (San Francisco, CA), secure and confidential platforms. The original and adapted study was approved by the University of Michigan's Institutional Review Board (HUM00173043). The methods we adapted for each research variable are outlined below. See **Table 1** for comparison of the original vs. adapted methods by research variable.

TABLE 1 | Previous and adapted methods by research variable.

Variables	Assessment	Original methods	Adapted methods	Data
Demographics	Parent questionnaire	Parent questionnaire; pen and paper	Qualtrics	Age, gender, race, relation to child, socioeconomic status
Anthropometrics	Stadiometer and body composition analyzer	Researcher assessed	Qualtrics; self-reported	Height (cm), weight (lbs.), & BMI calculated of parent and child
Physical activity	Actigraph gt3x or gt3x+; 7-day wear protocol	Handed directly to participant	Mailed through USPS	Minutes/ day spent in MVPA & light, moderate, & vigorous activity
Motor competence	Process measures	Researcher administered full TGMD-3	Catch, jump, throw, and kick	Raw score (range 0–30)
	Product measures	Kick and throw speed, jump distance, and catch percentage	Jump distance and catch percentage	Cm and percentage
	Process and product	Researcher administered	Participant recorded videos	Z-scores
Perceived competence	Self-perception profile for adults and children; pictorial scale of perceived movement skill competence	Researcher administered; both assessments	Qualtrics; only Self-Perception Profile for Adults & Children	Perceived competence score; athletic competence, physical appearance, and global self-worth (range 1–4)
Beliefs	Semi-structured interview	Interview conducted in participant home	Zoom application	Themes

MVPA, moderate to vigorous physical activity.

Demographics and Anthropometrics

Parents self-reported demographics and anthropometrics for themselves and their child through Qualtrics (Provo, UT).

Physical Activity

Parent-child dyads were mailed Actigraph gt3x or gt3x+ trial-axis accelerometers (Actigraph LLC., Pensacola, FL), directions on how to wear the accelerometer for a 7-day wear period, a physical activity log to manually record wear time, and a prepaid return envelope. Mailings were distributed through the United States Postal Service (USPS).

Motor Competence

The authors' created an online motor competence assessment. This assessment was adapted from existing and validated motor assessments; the Test of Gross Motor Development-3 (ICC = 0.97) (39) and product assessments that are sensitive discriminators (40–42). The first author (KQS) and two experts in Motor Development with over 10 years of experience in researching and administering motor skills developed and coded the assessment. Due to limitations with at-home administration, the online motor skills assessment only included four motor skills (i.e., catch, jump, kick, and throw). The catch, jump, kick and throw were assessed using the performance criterion of the Test of Gross Motor Development-3 (39) performance criterion. The product of catch percentage and jump distance were assessed through video software Dartfish (Pro6, Fribourg, Switzerland) (40–42). Aggregate process and product scores were created by standardizing the process and product measures and summing the created z-scores to develop the motor competence variable (41, 43, 44).

Parent-child dyads were emailed directions on how to perform the four different motor skills at home and film their performance. Parent-child dyads were instructed to gather the following equipment: a smartphone, tablet, or another filming device, a small ball/object to throw and catch, a larger ball or equivalent to kick, and optional measuring tape for the jump. Each motor skill had a corresponding multimedia demonstration available on YouTube. Multimedia demonstrations are an appropriate medium to use with the administration of motor assessments to ensure consistency in the demonstration (45).

The parent-child dyads were first instructed to watch the motor skills corresponding multimedia demonstration for each motor skill. Next, the directions instructed the parent-child dyads to perform one practice trial and watch the multimedia demonstration again. Then, the parent-child dyads performed two test trials for the throw and kick or five test trials for the catch and jump. This sequence was completed for each skill. This sequence was developed based on the standard protocol for administering the TGMD-3 (39) and has been used in administering product and process motor skills (41). In these standard protocols, participants perform one practice and two or five test trials for each motor skill. A skill demonstration is administered before the test trial, and if needed, again before the first test trial. The participant (i.e., the parent or child) not performing the motor skill was instructed to film the other participant's performance. Once all four motor skills were performed and filmed by both the parent and child, they uploaded their motor skills videos into their personal Box (Redwood City, CA) or Dropbox (San Francisco, CA) folder.

Perceived Competence

We administered the perceived competence assessment, The Self-Perceptions Profile for Adults ($\alpha = 0.81$–0.92) and Children ($\alpha = 0.76$–0.91) (46, 47), through Qualtrics (Provo, UT). The Self-Perceptions Profile for Adults and Children (46, 47) domains of athletic competence, physical appearance, and global self-worth were used to assess perceived competence. Qualtrics is

an experience management company that specializes in research software and survey development (Provo, UT).

Beliefs

Semi-structured interviews were conducted, audio-recorded, and transcribed through Zoom (San Jose, CA) to examine beliefs. The Zoom (San Jose, CA) interviews were password-protected to ensure confidentiality.

RESULTS

The results of this study demonstrate *solution testing* (i.e., feasibility) of the adapted methodology (38).

Recruitment

A total of 200 families expressed interest in this study, defined as sending an email to the research team or clicking on "Interested in Participation" on the University Research Registry. A total of 76 parent-child dyads consented and assented to be part of this study. Fifteen parent-child dyads dropped out of this study for various reasons: no response, lack of time, and health issues. Sixty-one parent-child dyads completed at least one part of the study.

Data Collection

For physical activity, a total of 50 parents and 48 children had valid physical activity data, defined as four valid days of wear time ($\geq$10 h of wear time per day) (48, 49). A total of 43 parents had a computed motor competence score, 46 parents completed process measures, 49 parents completed catch percentage, and 44 parents completed maximum jump distance. A total of 45 children had a computed motor competence score, 48 children completed process measures, 49 children completed catch percentage, and 47 children completed maximum jump distance. A total of 57 parents and 49 children completed the perceived competence assessment. A total of 12 purposefully selected parent-child dyads participated in the semi-structured interviews.

Data Quality

For physical activity, nine accelerometers were lost through USPS mail service and a participant lost one accelerometer. A total of 8 parent-child dyads did not follow the motor competence assessment directions; they did not upload all the motor skills, had problems either filming and/or uploading videos, or their videos that could not be coded. There were 4 parents and 10 children who did not complete the perceived competence assessment accurately. Interviews were not conducted in the parent-child dyad homes, making it challenging to build rapport.

DISCUSSION

This study demonstrated that conducting online human subject research assessing associations of and beliefs about physical activity, motor competence, and perceived competence is feasible, however, it is important to discuss the challenges we faced.

Recruitment

The aim of the recruitment methods employed in this study was to reach all eligible participants. Using multiple online platforms for recruitment was done intentionally to have a broad reach across the entire state of Michigan, however the recruitment methods lead to bias. The parent-child dyads' geographic location was centralized to Southeastern Michigan. A few parent-child dyads from Southwestern Michigan, but none from Northern Michigan participated in this study. Also, the sample was majority White, educated, and middle to high socio-economic status (see **Table 2**). Parents were 88.5% White and children were 75.4% White, parents had high levels of education (52.5% held a graduate degree or higher), and total household income was high (46% was $100,000 and above). This was an exploratory study of online research amid a global pandemic. Thus, conducting this research with this population demonstrates online research is feasible. In terms of application, future recruitment for online research must focus on the inclusion of how to have a wider reach and more diverse populations. For better recruitment methods, recommendations should be taken from online survey researchers (50, 51). Best practice for survey research addresses how to develop sampling methodology, obtain higher response rates, representativeness, and use of quality methodologies (50, 51). Future research must address targeting a more diverse, inclusive, and representative sample to ensure quality and rigor (50).

Another challenge with recruitment was getting participants to consent and assent, and the high rate of dropout (approximately 20%). Expressing interest was defined as sending an email to the research team or clicking on "Interested in Participation" on the University Research Registry. Even after reaching out to interested participants multiple times and through various methods, we could not get a higher rate of participants' consent and assent for participation in this study. Low response rates are common for online research (52), but a low percentage consented and assented even after expressing interest. Lack of study participation or consenting can partially be attributed to technological issues, discussed more below.

Data Collection

This study utilized numerous online platforms that were challenging for participants to use. Parents had difficulties using the platforms Box (Redwood City, CA) and Dropbox (San Francisco, CA). These platforms required parents first to create an account and then download, upload, and share files. The applications were difficult to use on participants' mobile phones or tablets compared to a computer, but they were continuously being updated and became more user-friendly as the study progressed. In terms of application, utilizing multiple, user-friendly platforms is encouraged for online research (52). Technological challenges have been noted as a problem with conducting research with marginalized populations (53), and technological issues likely contributed to the sample that participated in this study. The two online platforms were complex for parents to use and a potential reason why participants did not consent and assent to the study, dropped out, or did not complete the motor competence

TABLE 2 | Socio-demographic characteristics of parents.

	Overall % ($n = 61$)
Relationship to the child	
Mother	83.6
Father	16.4
Age	
20–29	1.6
30–39	47.5
40–49	47.5
50–59	3.3
Ethnicity	
White	88.5
Hispanic or Latino	1.6
Black or African American	3.3
Asian	1.6
Mixed ethnicity	4.9
Highest level of education	
High school degree or equivalent	1.6
Some college but no degree	11.5
Associate degree	4.9
Bachelor degree	29.5
Graduate degree or higher	52.5
Total number of adults in household	
1	6.6
2	88.5
3	4.9
4	0
≥ 5	0
Total household income	
≤ $24,999	9.8
$25,000–$49,999	9.8
$50,000–$99,999	34.4
$100,000–$149,999	23
≥ $150,000	23
Total number of children in household	
1	9.8
2	47.5
3	26.2
4	14.8
≥ 5	1.6
Weight classification	
Underweight	0
Normal	45.9
Overweight	24.6
Obese	29.5

assessment. For the most part, parents and children did not have trouble using Qualtrics (Provo, UT) to complete the perceived competence measure. However, the assessment was not fully compatible with this platform. Parent-child dyads did not have any trouble with the application Zoom (San Jose, CA) for the semi-structured interviews.

Data Quality

A significant challenge of conducting this online study was the lack of online motor competence and perceived competence assessments. The assessment was feasible for parents and children to complete in their homes without the presence of a researcher, however, the created motor competence assessment had significant limitations. The motor competence variable only included four process and two product skills. Therefore, only six measurements were combined to develop an overall motor competence score. The four motor skills did not fully assess the domains of FMS, as there was only one locomotor skill and three ball skills.

Another limitation was test administration. There is no way to assess if participants followed the directions as instructed. This online motor competence assessment was self-administered by parents and children; however, motor competence assessments are generally administered by trained researchers (54). There was no way to assess if parents and children accurately followed the sequence of administration (i.e., watch the multimedia demonstration, complete one practice trial, re-watch the multimedia demonstration, and then complete test trials). This sequence was developed based on the standard protocol for administering the TGMD-3 (39) and has been used in administering product and process skills (41). If parents and children did not follow this sequence, it might have further threatened validity. Also, the quality of the motor skill videos varied. For example, many videos followed the ball rather than the participant's body, making coding challenges. For future research application, an online motor competence assessment needs to be developed that accurately assesses motor competence and considers limitations of participant test administration.

We converted validated paper-based perceived competence assessments to the online platform Qualtrics (Provo, UT) for perceived competence. However, the platform was not ideal. The Self-Perception Profile for Adults and Children consists of a four-choice structured-alternative format (46, 47), and the configuration was not fully compatible. Additionally, there is no way to determine if parents and children who completed the assessment understood the format. These errors may have impacted the perceived competence variable. In terms of application, online platforms, such as Quatrics (Provo, UT), are continually updated and are becoming more compatible with varying assessments. Converted paper-based and in-person assessments should be tested for online validity and reliability.

CONCLUSION

The purpose of this study was to describe our process of adapting our study design during the COVID-19 pandemic to account for social distancing and shutdowns, and to examine feasibility and challenges of doing so. This study demonstrated that online research is feasible for examining associations of and beliefs about physical activity, motor competence, and perceived competence and can contribute significantly to advances in scientific knowledge. Important implications of conducting

online research include reaching a wider range of participants and being more cost-efficient. Future research must address the challenges this study experienced, specifically focusing on recruitment, technological issues, and assessment methodology. Future research can continue exploring and encouraging motor development in children and parents by addressing these challenges, as this research is critical for supporting low physical activity levels. The ease and accessibility of online research will create endless possibilities for research in motor development.

Due to the COVID-19 pandemic, it appears our society has become accustomed to an online world. Almost everything was conducted online or remotely from work, school, research, doctor visits, food delivery, and even social events throughout the pandemic. As the United States and the whole world slowly emerged from the COVID-19 pandemic, our society will forever be altered, and many things will continue to be conducted online due to ease and accessibility. When feasible, we believe research will continue to have some online or remote component, and this study demonstrated that it is possible. There are many advantages to conducting online research, including wide-reach recruitment methods and ease of participant burden, however, there were numerous challenges that we faced. This research adds to scientific knowledge because it shows the feasibility of adapting data collection to a societal and world-wide event and highlights challenges that must be addressed for future application.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author and must follow the proper data sharing procedures (i.e.., data sharing agreement and human subjects approval).

ETHICS STATEMENT

This study involved human participants and was reviewed and approved by the University of Michigan Ann Arbor, Institutional Review Board. For parent participants, written informed consent was provided. For child participants, written informed consent was provided by the child's legal guardian/next of kin and written assent was provided.

AUTHOR CONTRIBUTIONS

This work was part of KS-A dissertation research project. KS-A, RH, AM, TT, and LR: conceptualization, methodology, and writing—review and editing. KS-A: formal analysis, data curation, and funding acquisition. KS-A and LR: writing—original draft preparation. All authors have read and agreed to the published version of the manuscript.

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Affordances of School Ground Environments for Physical Activity: A Case Study on 10- and 12-Year-Old Children in a Norwegian Primary School

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Several studies have focused on how different school ground environments can stimulate physical activity (PA) in children. This study aimed to investigate the contributions of two school ground environments (a constructed schoolyard and a natural forest) in moderate to vigorous physical activity (MVPA) of Norwegian school children in the 5th and 7th grades. This study described two school ground environments that provided large and multifunctional spaces, giving the children several affordances for being physically active during the school day. The constructed schoolyard afforded a space of 44 m^2 per child and had an access to sports and game courts and various types of equipment for PA. The natural forest provided a space of 50.6 m^2 per child and had a varied landscape for activities that afforded a wide range of PA. On average, the children engaged in 50% of the 60-min period of MVPA when playing in the natural and constructed play settings. The two different environments, thus, contributed equally to the daily MVPA of the school children. The findings can inform policies and programs aiming at promoting recommended levels of PA among children using school outdoor environments that may eventually have implications for the physical and mental health of school children during the current pandemic.

Keywords: school children, physical activity, accelerometer, school ground environments, affordances

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INTRODUCTION

The positive effects of physical activity (PA) on children's health have been highlighted in many scientific studies (1–3) as well as international documents (4, 5). To promote a healthy lifestyle among school children, several countries, such as Norway, have adopted the global recommendation of at least 60 min of moderate to vigorous physical activity (MVPA) every day for children and youth.

Drawing on a population survey using accelerometers across Norway, the Norwegian Directorate of Health (6) reported that in 9-year-olds, 64% of girls and 81% of boys met the global recommendation. Among 15-year-olds, equivalent proportions were 40 and 51%. The level of PA was found to decline by age. Gender differences existed in all age groups, showing that boys were more active than girls.

As attending school is compulsory for most children, especially in Western countries, schools have an important role in promoting PA throughout the school day. Children spend most of their daytime at school, and, consequently, school grounds are important arenas that can be used to facilitate PA in children (7). Bell and Dyment (8) found that school-aged children spend ∼25% of their school day on school grounds, making schools important sites to engage children at healthy levels of physical activity. A recent study on Nordic-Baltic schoolyards found a gap between the design of schoolyards and school childern's preferences (9), indicating the need for more knowledge of children's needs and preferences of school ground affordances.

To ensure that school-aged children meet the recommended level of PA, the Norwegian Ministry of Education introduced the Amendment to the Act of Education in 2009 (10). In this Amendment, schools were instructed to provide 60 min of extracurricular PA a week for school children in grades 5–7 (10, 11, and 12 years old), in addition to existing physical education lessons. Thus, schools were supposed to provide more physically active and varied school days to meet the global recommendation of daily PA. Several Norwegian schools use their school ground environments to implement the Amendment. A national evaluation report indicated that these regulations are somehow difficult to implement (11). The evaluation also demanded more reports and research on the implementation of the mandate and its success in practice. Indeed, there is evidence from other studies that characteristics of the physical environment around schools may influence children's PA levels (12, 13).

In Norwegian schools, the tradition is to be outdoors using their school grounds for PA both during recess and in physical education classes. In fact, being outdoors is part of the Norwegian culture and a natural as well as integrated part of the school day. Norwegian guidelines (14) recommend an outdoor space of 30 m^2 per child in relation to the number of students in a school. Facilities of a school ground should be varied and customized to different age groups and functions. The physical outdoor environment around a school may vary according to geography and location, rural, or urban (14).

Earlier research suggests that children accumulate more PAs when playing outdoors than indoors, as outdoor environments promote more PAs than indoor environments (15, 16). For example, Cooper et al. (17) found that the intensity of PA was significantly higher outdoors than indoors. It is likely that environmental factors may influence PA levels in children, although these are dependent on the facilities provided (18–20). The authors observed that infrastructures, such as buildings, roads, and pavements, were used for light activities, and that green environments, such as gardens, parks, grassland, and farmland, were supportive of vigorous activities. Furthermore, Mårtensson et al. (21) found that settings with a mixture of green and built environments were favorite playgrounds during recess in 10–13 year-olds. Their findings are in line with those of (22) who found that school physical environment was the most effective means of enhancing PA in children. Thus, school ground environments may afford opportunities for PA, and the contextual diversity of schoolyards and natural environments appear to be crucial for promoting PA (18). An observational study on children's behaviors across two playgrounds found that fixed equipment and open play spaces encourage various levels of play and physical activity (23). Despite the contribution of these earlier studies, there is a knowledge gap regarding affordances of school ground environments for children's physical activity.

The physical environment of school grounds refers to objects and structures that turn landscapes into learning arenas and tasks that are stimulating, challenging, explorative, and diverse (24). Gibson's theory of affordances (25) explains how a physical environment can provide a context for human behavior and learning. Physical environments stimulate different behaviors and offer usage possibilities that are linked to affordances of a specific environment. Affordances of an environment can be potential and/or actualized (25, 26). Potential affordances refer to all possibilities that an environment offers, e.g., rocks can afford climbing, and an open field may afford running and jumping. Actualized affordances are the context between a physical environment and a child, which is expressed by the response of the child and visualized through specific types of physical activity, which may reflect different intensity levels of respective activities promoted by different affordances of environments. This response can be observed or measured as the activity of a child. Heft (27) defined affordances as functional characteristics of environmental features that are significant for an individual, introducing concepts of environmental features to be usable, like something that fits the hand becomes "throw-able", a tree or a rock being "climb-able", and an open space being "run-able". Lerstrup and van den Bosch (28) have used the taxonomy of Heft in describing how pre-school children are using traditional outdoor playground contra a forest, indicating the importance of the user-environment activity relationship.

In this study, potential affordances are possibilities in environments that may offer physical activity to school children. Our main aim was to map potential affordances for physical activity in two school environments as well as monitor the level of physical activity in 10- and 12-year-old school children in the two different environments during a 60-min extracurricular PA a week provided to these age groups (10).

The following research questions were examined:

1. What are the potential affordances for PA in the two school ground environments, the constructed schoolyard and the natural forest?
2. How do the two school ground environments afford MVPA in schoolchildren?
3. How do the two school ground environments afford MVPA across grades and gender?

With these research questions, we explored how the 60-min extracurricular PA a week (the National Amendment) met the national and global recommendations for daily PA in school children.

MATERIALS AND METHODS

Study Design

This was a descriptive case study with a quasi-experimental design (29), and it included two groups (school-aged children in the 5th and 7th grades) but had no control group. The independent variables are the constructed schoolyard and the natural forest together with their respective affordances for PA. The dependent variable is the PA levels in children in the two school ground environments measured with accelerometers.

Case Selection and Participants

A primary school located in a rural area of south-eastern Norway with a diverse and multifunctional school ground including a natural forest was selected as the case for this study. The selected primary school had a total of 200 pupils in grades 1–7 (6–12 years). School children in grade 5, ∼10 years old ($n = 27$, 16 boys and 11 girls) and grade 7, ∼12 years old ($n = 28$, 15 boys and 13 girls) were selected as participants for the study. To accommodate the Amendment to the Act of Education (10), these two school classes were each assigned by the school authorities to have 60 min of extracurricular PA a week during a school year.

Collection of Data

All school children in grades 5 and 7 in the case study school were eligible to participate. Children's participation in this study was voluntary and in accordance with the Declaration of Helsinki. Written consent was obtained from the school and parents prior to the study. All monitoring, collection of data, and analysis were treated anonymously and in line with ethical guidelines. The project was approved by the NSD-Norwegian Centre for Research Data. The collection of data included mapping and describing the two school ground environments and facilities for PA. The PA of the experimental groups was objectively monitored using accelerometers during the 60-min period in the two school ground environments.

Mapping and Describing Potential Affordances of School Ground Environments

The school was located in a rural area of an agricultural district. The school ground constituted a constructed schoolyard and a natural forest, and was mapped using a standard registration form for field observations to identify school ground areas, facilities, and landscape characteristics around the school area as well as potential affordances for PA (30). Ortophoto maps (Google maps: Norway in pictures, 2010; https://maps.google.no/maps) were applied as a basic source for visualizing the school ground and elaborated further into a topographic map (Norgeskart.no) visualizing environmental qualities of the two schoolyard landscapes. Mapping results were processed with illustrator tools using the program Adobe Illustrator CC. The two school ground environments were mapped and described by the authors, indicating landscape qualities and facilities that potentially afforded PA in the children.

Assessment of Physical Activity

We assessed the PA of the school children in accordance with the global and national recommendations for PA in children and adolescents. These recommendations require at least an average of 60 min per day of MVPA of mostly aerobic physical activity (5, 31), and are according to the guidelines from Utdanningsdirektoratet (10). The PA of 5th- and 7th-grade children was monitored for 60 min in the schoolyard and 60 min in the natural forest on two different school days. Each grade was measured once in each environment. In the two environments, the children could freely engage in different activities without the direction of teachers. The study was conducted in early autumn with a mean temperature of 10–12°C and good weather conditions (not raining).

Monitoring of Physical Activity

Accelerometers, *ActiGraph GT1M* (Actigraph, LLC, Fort Walton Beach, FL, United States) were used to monitor PA. The ActiGraph GT1M is a sturdy and compact dual-axis accelerometer that measures and records steps during vertical activities. The pupils were instructed to fix the accelerometer in the right hip position. Monitoring time of the PA was 60 min for each grade in each of the school ground environments. An epoch period of 10 s was selected for monitoring PA, which corresponded with earlier Norwegian surveys on PA in children and youth (6). The instrument measures vertical movements related to duration, intensity, frequency, and variation over time (Actigraph LLC, Pensacola, FL, U.S.). The cutoff point for MVPA was defined as 2,000 counts per minute. This cutoff point has been used in previous studies to define MVPA (32–34) and is comparable to the age-specific cutoff for 8.5-year-old children (35). The cutoff point at 2,000 counts per minute has been applied in previous Norwegian surveys on PA in children and youth (6).

Analysis of Data

Three school children out of the initial 55 participants in the study dropped out. The analysis of data, therefore, included PA levels from 52 school children. Descriptive analyses were conducted for PA levels in the constructed schoolyard and the natural forest across grades and gender. A series of independent sample *t*-test analyses was conducted to determine differences in MVPA levels on the two school ground environments across gender and grade. In addition, paired sample *t*-tests were carried out to assess differences in gender and grade with respect to MVPA levels in the two school ground environments. A two-way ANOVA was conducted to examine the main and interactive effect of grade and gender on PA levels in the two school ground environments. All the analyses were conducted using the SPSS statistical program.

RESULTS

Affordances for Physical Activity in the School Ground Environments

The two school ground environments constituted a total area of 19,007 m^2, providing an area of 95 m^2 per child. Thus, in

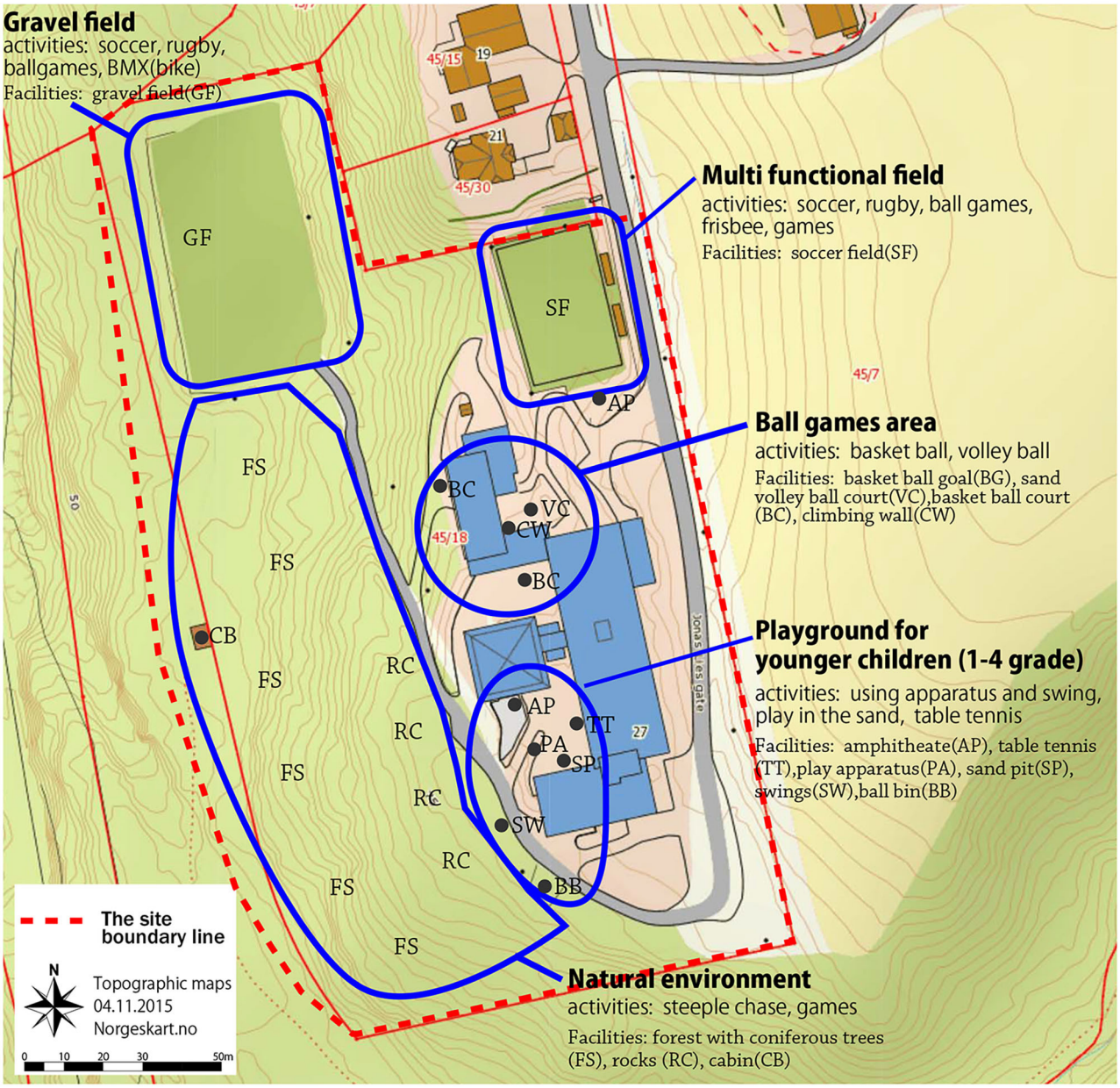

FIGURE 1 | School ground environments including the constructed school yard (multifunctional field, ball game areas, playground for younger children (grades 1–4), gravel field and natural environment consisting of a natural forest (FS), rocks (RC), and cabin (CB).

comparison to the recommended school space of 30 m^2 per child (14), the total school ground was assessed by the authors as large, varied, and multifunctional with many and diverse affordances for PA. The constructed schoolyard (8,874 m^2; 44 m^2 per child) constituted a multifunctional field affording traditional games and ballgames. Loose materials, such as balls, skipping ropes, space hoppers, Frisbees, and badminton equipment were also available on the multifunctional field (**Figures 1**, **2A**). Sports and ball game courts for basketball, volleyball, handball, and soccer were available (**Figures 1**, BC, VC, SF, **2C,D**). In addition, there was a climbing wall in one of the school buildings (**Figures 1**, CW, **2B**). All these facilities potentially afforded versatile PAs, such as running, jumping, climbing, throwing, sliding, and biking and were available to the children during the extra 60 min of PA.

The natural forest, which consisted of a mixed coniferous forest, had an area of 10,133 m^2 (50.6 m^2 per child) and varied topography including hills, slopes, and rocks, and a mixed vegetation of trees, bushes, heather, and grass (**Figure 1** FS, RC). The forest had potential affordances for PAs, such as steeplechase and jungle gym, hide and seek, and different kinds of traditional

FIGURE 2 | School ground environments showing potential affordances for different activities: The constructed schoolyard environments: **(A)** the multifunctional ballgame court, **(B)** the climbing wall with a soft cover substrate, **(C)** the basketball court, **(D)** the volleyball/ball game court. Environmental affordances of the natural forest: **(E)** cross-country running and hide-and-seek; **(F)** jungle gym, climbing, and balancing; **(G)** climbing and bouldering; **(H)** cross-country running (high speed).

games. Opportunities for climbing trees and rocks afforded a wide range of body movements (**Figures 1**, FS, RC, **2E,F**). Small paths indicated affordances for running, bushes for hiding, loose materials for constructions, e.g., small cabins, as well as cones and sticks that afforded throwing (**Figures 2E–G**). All these affordances were available to the children during the extra 60 min of free play.

The gravel field (**Figure 1** GF) was located next to the forest and was mainly used for activities, such as soccer, rugby, traditional games, and BMX/bikes. The cabin (CB in **Figure 1**) located in the forest functioned as a classroom for outdoor learning.

How School Ground Environments Afforded MVPA in School Children

In the results (not presented in Tables), PA monitoring with accelerometers showed that within a period of 60 min, about half of the participants in the total sample spent 30 min or more in MVPA in each of the two school ground environments: 51.9% in the natural forest vs. 51.1% in the constructed schoolyard. Thus, half of the children were almost equally active in each of the two school ground environments.

Environmental Affordances of MVPA Across Grades and Gender

Results from the frequency analysis (not presented in tables) showed that mean time spent in MVPA among the school children ranged from 7.4 to 39.2 min in a period of 60 min playtime in the natural forest and from 5.4 to 54 min in a similar playtime period in the constructed schoolyard. Thus, PA in the constructed schoolyard promoted the maximum time (54 min) in MVPA, which was registered by a 5th-grade boy. In **Table 1**, independent t-test only revealed gender differences in the schoolyard. The boys in in fifth grade spent more time in MVPA (a mean time of 39,18 min) compared to the girls (mean time 23,22 min). Paired sample *t*-test indicated within-gender differences in the 5th grade, where the boys spent more time in MVPA in the schoolyard (a mean time of 39.18 min) relative to their time spent in MVPA in the natural forest (a mean time of 31.63 min), although the significant level was only marginal. The opposite was true for the 5th grade girls, where a lower mean time of 23.22 min in MVPA in the constructed schoolyard was registered compared to their mean time of 31.52 min in the natural forest. There were no within or in-between gender differences in MVPA mean scores in the 7th grade concerning the two school ground environments (**Table 1**).

As shown in **Table 2**, a two-way ANOVA is performed to assess the main and interaction effects of grade and gender on time spent in MVPA in the constructed schoolyard and the natural forest. The results showed a significant main effect of gender: $F_{(1,43)} = 9.51$, $p = 0.004$, indicating a significant difference between the boys ($M = 34.43$, $SD = 10.93$) and the girls ($M = 25.37$, $SD = 9.15$) and an interaction effect between grade and gender ($p = 0.013$) on time spent in MVPA in the schoolyard. Specifically, the boys spent more time in MVPA in the schoolyard, while the interaction effect confirmed that this observation was mainly among boys in the 5th grade. The explained variance of the model for time spent in MVPA in the schoolyard was about 27%. There were no significant main or interaction effects of grade and gender on time spent in MVPA in the natural forest (**Table 2**).

TABLE 1 | Time spent (in min) in moderate-to-vigorous physical activity (MVPA) among school children in the natural forest and constructed schoolyard: a series of *t*-test analyses.

Grade	**Gender**						***t***	***df***	***sig.***
	Boys			**Girls**					
	M	***SD***	***n***	***M***	***SD***	***n***			
5th									
Natural forest	30.70	7.90	16	31.52	6.00	9	−0.27	23	0.516
Schoolyard	39.18	8.88	15	23.22	5.30	9	4.87	22	**0.001**
7th									
Natural forest	28.94	7.61	15	26.54	4.39	12	0.97	25	0.542
Schoolyard	28.51	10.62	12	27.13	11.36	11	0.30	21	0.954
Gender	**Grade**						***t***	***df***	***sig.***
	5th			**7th**					
	M	***SD***	***n***	***M***	***SD***	***n***			
Boys									
Natural forest	30.70	7.90	16	28.94	7.61	15	0.63	29	0.531
Schoolyard	39.18	8.88	15	28.51	10.62	12	2.85	25	0.548
Girls									
Natural forest	31.52	6.00	9	26.54	4.39	12	2.20	19	0.326
Schoolyard	23.22	5.30	9	27.13	11.36	11	−0.95	18	0.098
Grade	**School grounds**						***t***	***df***	***sig.***
	Natural forest			**Schoolyard**					
	M	***SD***	***n***	***M***	***SD***	***n***			
5th									
Boys	31.63	7.20	15	39.18	8.88	15	−1.99	14	0.066
Girls	31.52	6.00	9	23.22	5.30	9	2.45	8	**0.040**
7th									
Boys	30.58	5.32	12	28.51	10.62	12	0.68	11	0.513
Girls	26.77	4.66	10	25.97	11.27	10	0.22	9	0.833

M, mean; SD, standard deviation. Bold and italic values highlights the significant differences of results.

Summary of Results

This study showed how two school ground environments stimulated PA in school children. The total space of the school ground of 19,007 m^2 provided a total area of 95 m^2 per child, of which 44 m^2 constituted the constructed schoolyard and 50.6 m^2 the natural forest. Space per child was even larger when only one class of 12–16 children was outdoors at a time. Affordances in the constructed schoolyard and the natural forest supported almost equally the MPA levels in 10- and 12- year-old school children. On average, children engaged in ∼50% of the 60-min period of

TABLE 2 | Time spent in MVPA in the natural forest and constructed schoolyard across grade and gender: a two-way analysis of variance.

Source	Type III Sum of Squares	*df*	Mean square	*F*	Sig.
Time spent in MVPA in natural forest					
Grade	140.40	1	140.40	3.00	0.090
Gender	7.68	1	7.68	0.16	0.687
Interaction (Grade * Gender)	32.05	1	32.05	0.68	0.412
Error	2,246.60	48	46.80		
Total	47,285.67	52			
Corrected Total	2,415.36	51			
R squared = 0.07 (adjusted R squared = 0.012)					
Time spent in MVPA in constructed schoolyard					
Grade	130.70	1	130.70	1.45	0.235
Gender	854.03	1	854.03	9.51	***0.004***
Interaction (Grade * Gender)	603.60	1	603.60	6.72	***0.013***
Error	3,860.91	43	89.79		
Total	48,587.92	47			
Corrected Total	5,640.18	46			
R squared = 0.315 (adjusted R squared = 0.268)					

Bold and italic values highlights the significant differences of results.

moderate- to vigorous-intensity PA when playing in the natural and constructed play settings. Differences in activity levels were observed between the boys and the girls in grade 5 but not in grade 7.

Despite environmental differences between the two school ground environments, a multifunctional constructed schoolyard and a natural forest, both environments appeared to afford high levels of PA. Generally, the results showed little to no differences in PA in the two school ground environments across grade and gender in relation to time spent in MVPA. Specifically, boys in the 5th grade spent more time in MVPA in the constructed schoolyard than other school children in the sample.

DISCUSSION

Potential affordances for PA in the two school ground environments were seen as multifunctional with various much space-affording options for PAs. The results showed that both the natural forest and the constructed schoolyard generated MVPA in the schoolchildren. With a total area of 19,007 m^2, the school ground environments provided an area of almost 51 m^2 per child in the natural forest and an area of 44 m^2 per child in the constructed schoolyard for PA, exceeding the Norwegian guidelines for an outdoor space of 30 m^2 per child in schools with a maximum 450 pupils (14). Space has been discussed in previous studies and appears to be a crucial factor for affordances of PA, especially for meeting the national and global recommendations for daily PA (18). School ground space has been documented in different Nordic and Baltic countries with different recommendations and regulations for space and design of schoolyards (9). As space is important for physical activity at high intensity, this should be important for future studies and designs of schoolyards.

The results showed that a variety of potential affordances in the two environments was associated with healthy levels of PA among the schoolchildren. Even though the actualized affordances of the two environments were not documented, the monitored levels of MVPA in the children in the two environments reflected positive environmental contexts for intensive PA in the two school grounds (see **Figure 2**). The constructed schoolyard constituted several open areas with asphalt, gravel, and artificial lawns, which were related to PA with high intensity (**Figures 2A,C,D**). Other facilities like the climbing wall, rocks, and rubber surface afforded varied PAs (**Figure 2B**). The natural forest afforded running and steeple chase in a rough terrain and different opportunities for PA (**Figures 2E–H**). Earlier studies have also documented the importance of green environments for play and PA (36–38). Morton et al. (39) conducted a review on the current evidence of school-based PA and physical environment using ninety-three studies on mixed methodological quality. Their findings showed that availability of sufficient space and facilities were considered important for high levels of PA. These findings are in line with our study documenting the importance of space and diversity in school ground environments.

Our findings are consistent with earlier studies on the role of green space and multifunctional school grounds in stimulating PA. For example, Bell and Dyment (8) examined the information provided by parents, teachers, and administrators across several elementary schools in Canada and found that green school grounds appeal to children's interests and support a wide variety of play opportunities that promoted PA. Furthermore, 20 observed that green environments supported vigorous PA, and that boulders, trees, and bushes appeared to encourage moderate PA. A recent study by 40 explored how secondary school students experienced and used school grounds of varying sizes, contents, and designs in PA. Their results indicated that large surface areas and varied contents with ball court, greenery, and multifunctional equipment were valued by students. Thus, creating more "activity-friendly" environments holds a promise for improving PA in school children (40) and students (41).

How the school ground environments afforded MVPA in the school children was monitored with accelerometers. The results showed that within the period of 60 min, about half of the participants in the total sample spent 30 min or more in MVPA in each of the two environments. This is a fundamental contribution to reaching the recommended 60 min of MVPA every day. Consistent with Bell and Dyment (8), the children spend a quarter of their school day in the schoolground. Consequently, school grounds are promising sites that can enable children to meet the recommended 60-min daily PA. Our study showed that access to adequate space and facilities is important for affording PA in school children, a finding that was also documented by (42). School outdoor environments, therefore, should be varied and multifunctional to afford many possibilities for PA among all children.

A main effect of gender and an interaction between grade and gender were found in time spent in MVPA in the constructed schoolyard but not in the natural forest. The findings showed that the boys, particularly those in the 5th grade, were more

physically active in the constructed schoolyard than the other school children in our sample. Our findings in the constructed schoolyard are somewhat in line with earlier research studies that have also shown a decline in PA levels with age as well as gender differences, where boys were more active than girls (6, 43, 44). However, there were no gender differences in MVPA in the natural forest, while within-gender differences revealed that girls in the 5th grade were more active at MVPA levels in the forest than in the schoolyard. This may indicate that the forest stimulated more actualized activities for the 5th grade girls than the constructed schoolyard. This needs to be better investigated in future studies with a larger sample along with comprehensive and systematic observations.

Our study on 60 min of extracurricular PA in 5- and 7th-grade school children confirmed that the environmental context for PA supports the national and global guidelines for daily PA in children (5, 31) and confirmed the purpose of the Amendment Act for PA in schools (10). Mainly focusing on the intensity of PA during the 60-min period, the results indicated that the level of recommended daily PA was successfully reached by 50% of the extracurricular time used for PA at intensity levels of MVPA. The finding is in line with a national study on PA in 9- and 15-year-old children (6).

An evaluation report of the Amendment Act of 60 minutes extracurricular PA a week, found no effects of the implementation of the mandate in the evaluated studies (11). Consequently, this study may provide relevant information on the positive effects of the Amendment Act, with focus on the context of supporting school environments.

STRENGTHS AND LIMITATIONS

Mapping the characteristics and qualities of school ground environments and examining differences in activity levels in the environments may contribute to the understanding of environmental contexts for promoting PA in school children. The use of accelerometry to quantify activity in the context of environmental affordances is a new methodological approach. This made it possible to describe contextual relations to the levels of PA during the extra 60 minutes a week provided for 5 to 7 graders (10).

The limitations include focus on one school, only examining boys and girls in two grades, and assessing activity levels once in each setting. Our study was limited to two groups, the 5th and 7th grades, and only one class in each grade was included in the study. Thus, our sample was small and may not be representative enough to make any generalized conclusion on PA and time spent in MVPA during the provided extra 60 min among Norwegian school children in grades 5–7, although our findings provide some indication of average level of activity. To increase the reliability and validity of future studies, more schools and school children in appropriate grades should be included in samples. In addition, applying accelerometers solely and achievement of MVPA as a measure for PA might be limitations, as they do not differentiate among qualities of movement patterns including climbing, coordination, and balance, which may not contribute to MVPA levels. Observations could have been conducted as additional methods for explaining how actualized environmental affordances promoted children's versatile movement patterns.

Furthermore, the study was carried out in only one season of the year, which was during early autumn when temperatures were mild and weather conditions were good. It is, therefore, not clear whether school children would be equally physically active if weather conditions were different or temperatures were harsher. As there are four seasons in Norway with unique climate conditions, the study will need to be replicated in all seasons to verify that the school ground environments indeed afford MVPA in school children independent of the season.

IMPLICATIONS AND CONCLUSION

Despite the limitations of this study, our findings revealed the importance of spacious and varied outdoor school ground environments in children's daily PA. Our findings indicated that diversity of outdoor environments is an important stimulator of daily PA in school children. There are only a few studies in this field, and the expectation is that our study will pave the way for future studies on affordances of school grounds and their relevance for PA in school children. To our knowledge, there are no other Norwegian studies that have described and validated the implementation and effects of the national amendment of extracurricular time for physical activity in 5- to 7th-grade school children. Our study showed that both the natural forest and the multifunctional constructed schoolyard that ensure acceptable play space are important for PA in the school children. This means that school ground environments can have a significant impact on children's PA and can effectively enable MVPA at recommended daily levels. The aspect of affordances should be more emphasized in future planning and renovation of school grounds, as different qualities of school ground landscapes and facilities may inspire children to have increased PA. The quality of school ground environments and impact on PA in children should have wider attention, and hopefully, this study may stimulate more studies in the field. Applying environmental mapping techniques and analyses of potential and actualized affordances for designing multifunctional schoolyards should be future methods in such processes. However, more research is needed to assess the quality and design of school grounds in terms of their affordances for PA, which can eventually help inform effective PA policy and practice. Accordingly, research evidence will expectantly influence policy-makers, planners, school administrators, and teachers to make school ground environments more attractive and stimulating for PA among school children.

In conclusion, this study described a constructed schoolyard and a natural forest that provided large spaces (a total area of 95 m^2 per child) and multifunctional school grounds,

giving the children several affordances for being physically active during the school day. While our study was not directly linked to the coronavirus disease-2019 (COVID-19) pandemic, the findings may have some implications in the physical and mental health of schoolchildren during the current pandemic. These findings can contribute to inform policies and programs to use school ground environments more effectively, not only to reduce the transmission of infection but also to enhance the physical and mental health of school children through healthy levels of PA as the pandemic continues to be unabated.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Norwegian Center for Research Data. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

NW has been responsible for the statistical analyses. All the authors have contributed equally to the manuscript.

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