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PHYSICAL ACTIVITY, HEALTH AND EXERCISE

Associations among motor competence, health-related fitness, and physical activity in children: A comparison of gold standard and field-based measures

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ABSTRACT

This study compared the associations among motor competence, health-related fitness, and physical activity measured by gold standard and field-based methods in children. A total of 248 first-grade children (153 boys) aged 6–7 years participated in the study. Motor competence was assessed using the Test of Gross Motor Development, Second Edition (TGMD −2). Gold standard measures were percent body fat using dual-energy X-ray absorptiometry, peak oxygen uptake per weight using a gas analyser, and moderate-to-vigorous physical activity using accelerometers. Field-based measures were body mass index, maximum speed during progressive running on a treadmill, and a physical activity questionnaire. Multiple regression analysis adjusted for age and sex was used to examine the associations of motor competence with one of the health-related variables and compared differences by measurement method. The results indicated that field-based measures models showed lower associations ($R^2 = 0.02$–0.17) than the gold standard ($R^2 = 0.21$–0.27) and lower standardised regression coefficients for sex and motor competence, except for maximum speed. In conclusion, gold standard measures resulted in stronger associations between motor competence, and health-related fitness and physical activity in children. Examining the contribution of motor competence in children's health using field-based tests can underestimate it.

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Locomotor skills; object control skills; percent body fat; VO_2peak; moderate-to-vigorous physical activity

Introduction

Motor competence refers to the mastery of physical skills and movement patterns such as locomotor, object control, and stability (Castelli & Valley, 2007), and supports participation in a range of physical activities (Barnett et al., 2020; Gallahue & Ozmun, 2006). However, systematic reviews examining the relationship among motor competence, health-related fitness, and physical activity have produced conflicting results (Barnett et al., 2016; Liu et al., 2023; Lubans et al., 2010; Robinson et al., 2015). A recent systematic review of longitudinal studies conducted by Barnett and colleagues (Barnett et al., 2022) found a strong negative bi-directional association between motor competence and weight status and a strong positive association between motor competence and health-related fitness. However, the authors found little evidence to support a bi-directional association between motor competence and physical activity. Notably, the studies included in previous reviews have used a wide range of measures to assess health-related fitness and physical activity. As such, there remains a need for comparative studies to examine associations using different field- and laboratory-based measures.

Gold standard measures are the most reliable, validated, and widely accepted methods available to researchers. For instance, percent body fat (%BF) using dual-energy X-ray absorptiometry (DXA) is considered the gold standard measure of body composition (Fowke & Matthews, 2010). Peak oxygen uptake per weight (VO_2peak) using a gas analyser (Armstrong, 2007), and accelerometers (Holfelder & Schott, 2014) are considered the gold standard measures for assessing aerobic capacity and moderate-to-vigorous physical activity (MVPA), respectively. However, these methods require complex experimental settings and can therefore be costly and time-consuming. To address these issues, field-based tests have been used as alternatives to the gold standard since they are time-efficient, low in cost, and can be easily administered to several individuals simultaneously. Contrastingly, field-based tests are less accurate, valid, and reliable than the gold standard (Castro-Piñero et al., 2010).

Body mass index (BMI) is a common field-based measure of weight status since it only requires height and weight data, hence it is easy to calculate, however, despite being useful for screening the weight status of a large population, BMI cannot accurately predict body composition (Castro-Piñero et al., 2010;

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Wang, 2004). The 20-metre multistage fitness test (also known as the beep test) is the most commonly used measure of aerobic fitness (Lang et al., 2018). As the correlation between the results of these tests (laps or final speed) and VO_2peak measured with a gas analyser showed a significant relationship, mathematical equations to estimate VO_2peak from the laps or final speed have been developed (Arsa et al., 2018). However, this correlation was moderate (Arsa et al., 2018; Tomkinson et al., 2019), in addition, physical maturation influences the test results, and the speed in the initial stage is so fast that most children fail to run continuously for the least 5 min (Tomkinson et al., 2019). Therefore, the laps or final speed might not sufficiently reflect physiological capacity. Questionnaires are another popular method used to assess physical activity; however, the correlation between the results of the questionnaires and objectively measured physical activity, such as pedometers and accelerometers, is small (Chinapaw et al., 2010).

Motor competence is essential to enhance future movement and physical activity and achieve appropriate levels of health-related fitness (Barnett et al., 2022). However, previous studies have often relied on field-based measures, even though there may be differences in the relationship depending on the measurement method employed. This means that these previous studies may not necessarily reflect the associations accurately. Additionally, it is especially important to focus on children in the first grades of primary school, as this is when compulsory education typically begins in many countries. Highlighting the importance of motor skills in early primary school could help shift attitudes towards physical education, benefiting children's engagement in physical activities not only during their primary school years but also extending into their preschool years. Therefore, the aim of our study was to compare the strength of associations among motor competence, health-related fitness, and physical activity using gold standard and field-based measures in children. We hypothesised that the gold standard measures would be more strongly associated with motor competence compared with the field-based measures.

Materials & methods

Study design and participants

We recruited first-grade children (153 boys and 95 girls) aged 6–7 years without special educational needs from three public schools and two schools affiliated with national universities in the Tokyo, Chiba, and Ibaraki prefectures (Aoyama et al., 2022, 2023; Hikihara et al., 2022). Anthropometry, motor competence, and health-related fitness tests were conducted between July and September 2012 and 2013 at either National Institute of Health and Nutrition or University of Tsukuba, Japan. Daily PA was measured using an accelerometer on 14 consecutive days during the school term (October and November of 2012 and 2013). Our study was approved by the ethics committees of the participating institutes. The study procedures were explained in writing to all the children and their parents, and informed consent was obtained from all the parents.

Motor competence

We used the Test of Gross Motor Development, Second Edition (TGMD –2) to determine motor competence. The TGMD – 2 is designed for children aged 3–10 years and provides a qualitative assessment of children's locomotor (LC) and object-control (OC) competency. The TGMD – 2 involves observations of movements across 12 tasks to assess LC (run, slide, leap, gallop, hop, and horizontal jump) and OC (overhand throw, underhand roll, catch, hand dribble, kick, and strike) skills. We calculated the total LC and OC scores using a checklist (Ulrich, 2000).

All movements were assessed by a trained research assistant. Before conducting the assessments, the research assistant was instructed on how to evaluate the movements and received training from a proficient assessor, who is a member of the research team with experience in assessing young children's motor skills. After completing this training, the assistant conducted the assessments. To confirm the reliability of the assessments, the proficient assessor independently evaluated a randomly selected sample of 40 children from the study participants ($N = 248$). The average scores between two assessors showed no significant differences, and the intraclass correlation coefficients between two assessors demonstrated high reliability, with values of 0.96 and 0.98 for LC and OC, respectively.

Health-related fitness

Anthropometry measurements. We measured body height and weight to the nearest 0.1 cm and 0.1 kg respectively and BMI was calculated. %BF was measured using DXA (Hologic QDR – 4500; Hologic, Inc., Waltham, MA, USA). These parameters were measured with participants wearing light underwear and no shoes. In this study, we defined %BF measured using DXA as the gold standard and BMI as the field-based measure.

Aerobic fitness. VO_2peak was measured as aerobic fitness. The test was conducted on a treadmill using the maximal increment protocol (Armstrong, 2007). The participants started by walking for 2 min at 4.2 km/h (70 m/min). In subsequent running, the gradient increased over time, while the speed was maintained at 6.0 km/h (100 m/min). The gradient was increased by 2.5% every 2 min from the start of running, and adjusted according to the sports participation of the participants, their heart rate, and conditions during the test so that the maximal speed was reached in 9–12 min. Exhaustion was judged following the guidelines (Armstrong, 2007). The reliability of aerobic testing with treadmills is at a satisfactory level in a previous study (Figueroa-Colon et al., 2000).

Expired gases were analysed using a gas analyser (Aero Monitor, AE310S, Minato Medical Science, Osaka, Japan). A silicone mask with an expired gas-collecting tube was positioned on the mouth and nose of each participant for breath-by -breath analysis during the test. Oxygen uptake data were averaged every 30 s and the VO_2peak data during the test were selected. Since this test involved a gradient progressive increase in running speed, the pattern was similar to 20-metre multistage fitness tests. Therefore, the maximum speed of this test reflected the results of the field test. However, we increased the inclination beyond the speed to maintain the safety of the participants. Using the equation of VO_2peak, speed, and gradient (Silverman & Anderson, 1972), a 1% increase in the gradient was equivalent to a speed increase of 0.278 km/h in oxygen uptake. Finally, we estimated the maximum speed under flat conditions applied to this relationship. In this study, we considered the VO_2peak measured by a gas analyser as the gold standard, and maximal speed on the treadmill running test as a field-based measure.

Physical activity

Physical activity was measured using a tri–axial accelerometer (Active style Pro, 350–IT, Omron Healthcare, Kyoto, Japan). This accelerometer is commonly used in Japan and is highly reliable in estimating physical activity intensity in children (Hikihara et al., 2014, 2021). The participants wore the accelerometer in an accessory pouch fastened by an elastic belt on their hips for the entire day, except during water-based activities and sleeping at night. The participants were asked to wear the device for 14 consecutive days. Accelerations were detected using a sampling rate of 32 Hz, analysed by 10-s epoch length, and converted into metabolic equivalents (METs) as previously described (Ohkawara et al., 2011). The METs for elementary school children were calculated using the following equation (Hikihara et al., 2014, 2021). Non-wear time for accelerometers was defined as periods of ≥20 min of zero counts (Esliger et al., 2005). The criterion for a valid day was ≥10 h of "wear time" accumulated between 07:00 (awakening time) and 21:00 (bedtime). This represents the average activity duration of Japanese elementary schoolchildren. All subjects who provided valid PA data for ≥ 5 weekdays and ≥ 2 weekend days in each year were included in each analysis (Trost et al., 2000). The average MVPA was defined as ≥ 3.0 METs and calculated by weighting the data for 5 weekdays and 2 weekends. A macro program developed and distributed by the Japan Physical Activity Research Platform (http://paplatform.umin.jp (in Japanese)) was used for data processing of the accelerometer.

Additionally, participants completed a validated physical activity questionnaire and were asked how many times per week they played sports or exercised, except for physical education classes on weekdays and weekends. Participants' parents answered this questionnaire instead of children. The same questionnaire is used by the National Physical Fitness Surveillance in Japan (Kidokoro et al., 2023; Ministry of Education, Culture, Sports, Science and Technology, 1999). No studies have tested the reliability of this questionnaire. However, studies that have tested the reliability of a similar questionnaire (HBSC: Health Behaviour in School-aged Children) have shown adequate reliability (Takakura et al., 2006). The average self-reported physical activity was calculated by weighting the data for 5 weekdays and 2 weekends along with the accelerometer data (Hikihara et al., 2022). We defined the MVPA measured using an accelerometer as the gold standard and exercise time assessed by a physical activity questionnaire as a field-based measure.

Statistical analyses

Descriptive statistics (mean and standard deviation, SD) of each variable were calculated according to sex. Before statistical analysis, self-reported physical activity was log-transformed. Correlation analysis was used to reveal the relationships among all variables. The significance of the difference between the two correlation coefficients was conducted between motor competence–gold standard and motor competence–field-based measures. The correlation coefficients were interpreted as $|r|<0.1$ as very small, $0.1\le|r|<0.3$ as small, $0.3\le|r|<0.5$ as moderate, and $0.5\le|r|$ as large (Cohen, 1988). Finally, multiple regression analysis was performed to assess the associations between motor between health-related fitness and physical activity (dependent variables: gold standard and field-based measures) and motor competence (independent variables: LC and OC), adjusting for age and sex. We interpreted the R^2 values as < 0.02 very small, $0.02\le R^2 <0.13$ small, $0.13\le R^2 <0.26$ moderate, and $0.26\le R^2$ large (Cohen, 1988). Statistical analyses were performed using Microsoft Excel and JMP version 14.0 (SAS Institute Inc. USA). The level of significance was set at $p < 0.05$.

Table 1. Descriptive statistics of all variables.

	Boys			Girls				
Variables	N	M	SD	N	M	SD	*p*	*d*
Age (year)	153	6.9	0.3	95	6.9	0.3	0.954	0.00
Height (cm)	153	119.7	5.1	95	117.9	4.3	0.004	0.38
Weight (kg)	153	21.9	3.0	95	21.2	2.7	0.059	0.24
Motor competence								
Total motor skill (score)	153	75.6	10.3	95	69.1	9.4	<0.01	0.65
Locomotor skills (score)	153	40.2	5.5	95	40.6	4.1	0.523	0.08
Object control skills (score)	153	35.4	7.0	95	28.5	6.8	<0.01	1.00
Adiposity								
%BF (%)	153	20.3	4.2	95	23.7	4.2	<0.01	0.81
BMI (kg/m^2)	153	15.2	1.3	95	15.2	1.5	0.889	0.00
Aerobic fitness								
VO_2peak (ml/kg/min)	153	51.0	5.1	95	46.9	5.1	<0.01	0.81
Maximum speed (km/h)	153	10.1	1.0	95	9.6	0.8	<0.01	0.54
Physical activity								
MVPA (min/day)	146	86.3	21.1	93	67.6	16.6	<0.01	0.97
Exercise time (min/day)	153	113.9	94.8	95	86.2	76.2	0.017	0.32

N: sample number, M: mean, SD: standard deviation, *d*: Effect size.
%BF: percent body fat, BMI: body mass index, VO_2peak: peak oxygen uptake per weight, MVPA: moderate-to-vigorous physical activity.

Table 2. Correlations among variables in each sex.

Variables	1	2	3	4	5	6	7	8	9
A: Boys									
1. Total motor skill	1	0.76**	0.92**	−0.35**	−0.22*	0.42**	0.35**	0.27**	0.14
2. LC		1	0.45**	−0.40**	−0.25*	0.30**	0.30**	0.15	0.04
3. OC			1	−0.24*	−0.15	0.40**	0.31**	0.28**	0.17
4. %BF				1	0.71**	−0.37**	−0.18	−0.28**	−0.09
5. BMI					1	−0.35**	−0.05	0.00	0.14
6. VO_2peak						1	0.55**	0.05	0.04
7. Maximum speed							1	0.05	0.23*
8. MVPA								1	0.21
9. Exercise time									1
Variables	1	2	3	4	5	6	7	8	9
B: Girls									
1. Total motor skill	1	0.77**	0.87**	−0.25**	0.03	0.23**	0.31**	0.35**	0.19*
2. LC		1	0.35**	−0.32**	−0.06	0.24**	0.30**	0.24**	0.08
3. OC			1	−0.11	0.10	0.15	0.22**	0.32**	0.21*
4. %BF				1	0.63**	−0.53**	−0.32**	−0.15	−0.26**
5. BMI					1	−0.38**	−0.11	0.20*	−0.04
6. VO_2peak						1	0.70**	0.00	0.24**
7. Maximum speed							1	0.16*	0.16
8. MVPA								1	0.16
9. Exercise time									1

*:$p < 0.05$, **:$p < 0.01$, LC: locomotor skills, OC: object control skills, %BF: percent body fat, BMI: body mass index, VO_2peak: peak oxygen uptake per weight, MVPA: moderate-to-vigorous physical activity.

Results

The descriptive statistics for all the variables are listed in Table 1, while the correlations among variables are listed in Table 2. Focusing on the relationship between the gold standard and field-based measures in boys and girls, a large significant correlation between %BF and BMI ($r = 0.63$ and 0.71, $p < 0.01$) and VO_2peak and maximal speed ($r = 0.70$ and 0.55, $p < 0.01$) was observed; however, there was no significant correlation between MVPA and exercise time ($r = 0.16$ and 0.21, $p \geq 0.05$). Concerning the relationship among LC and weight status, aerobic fitness, and physical activity, there was a small significant correlation in %BF ($r = –0.32$, $p < 0.01$), VO_2peak ($r = 0.24$, $p < 0.01$), maximum speed ($r = 0.30$, $p < 0.01$) and MVPA ($r = 0.24$, $p < 0.01$) in boys and %BF ($r = –0.40$, $p < 0.01$), BMI ($r = –0.25$, $p < 0.01$), VO_2peak ($r = 0.30$, $p < 0.01$) and maximum speed ($r = 0.30$, $p < 0.01$) in girls.

Next, concerning the relationship among OC and weight status, aerobic fitness, and physical activity, there was a small significant correlation in maximum speed ($r = 0.22$, $p < 0.01$), MVPA ($r = 0.32$, $p < 0.01$) and exercise time ($r = 0.21$, $p < 0.05$) in boys and %BF ($r = –0.24$, $p < 0.05$), VO_2peak ($r = 0.40$, $p < 0.01$), maximum speed ($r = 0.31$, $p < 0.01$) and MVPA ($r = 0.28$, $p < 0.01$) in girls. Finally, concerning the relationship between motor competence–gold standard and motor competence–field-based measures. Although the correlation coefficients of the motor competence–gold standard tended to be higher than those of motor competence–field-based measures, a significant difference was shown only between LC–%BF and LC–BMI (–0.32 and – 0.06, $p < 0.05$).

The results of the multiple regression analysis are shown in Tables 3 and 4. The model using field-based measures showed

Table 3. Results of multiple regression analysis setting gold standards as dependent variables.

Dependent variables	%BF ($R^2 = 0.25$)			VO_2peak ($R^2 = 0.21$)			MVPA ($R^2 = 0.27$)		
	B	SE	β	B	SE	β	B	SE	β
Intercept	20.1	6.17	0	44.5	7.69	0	73.1	29.3	0
Age	1.29	0.86	0.08	−0.38	1.07	−0.02	−2.65	4.10	−0.04
Sex	3.35	0.59	0.36**	−3.22	0.73	−0.29**	−13.82	2.80	−0.31**
LC	−0.28	0.05	−0.30**	0.19	0.07	0.18**	0.47	0.26	0.11
OC	−0.03	0.04	−0.05	0.13	0.05	0.18**	0.76	0.19	0.27**

*: $p < 0.05$, **: $p < 0.01$, B: partial regression coefficient, SE: standard error, β: standardized regression coefficient.
LC: locomotor skills, OC: object control skills, %BF: percent body fat, VO2peak: peak oxygen uptake per weight, MVPA: moderate-to-vigorous physical activity.
Sex: boys = 1, girls = 2.

Table 4. Results of multiple regression analysis setting field-based measures as dependent variables.

Dependent variables	BMI ($R^2 = 0.02$)			Maximum speed ($R^2 = 0.17$)			Exercise time ($R^2 = 0.07$)		
	B	SE	β	B	SE	β	B	SE	β
Intercept	14.1	2.13	0	6.39	1.42	0	4.37	1.39	0
Age	0.35	0.30	0.08	0.22	0.20	0.07	−0.104	0.192	−0.04
Sex	0.04	0.20	0.02	−0.40	0.14	−0.20**	−0.002	0.132	0.00
LC	−0.04	0.02	−0.14*	0.05	0.01	0.23**	−0.002	0.012	−0.01
OC	0.01	0.01	0.04	0.02	0.01	0.16*	0.026	0.009	0.23**

*: $p < 0.05$, **: $p < 0.01$, B: partial regression coefficient, SE: standard error, β: standardized regression coefficient.
LC: locomotor skills, OC: object control skills, BMI: body mass index Sex: boys = 1, girls = 2.

lower determinants of coefficients ($R^2 = 0.02 – 0.17$) than the gold standard ($R^2 = 0.21 – 0.27$). However, the difference in R^2 between VO_2peak and maximum speed was small ($R^2 = 0.21$ and 0.17, respectively). Concerning the standardised regression coefficient, although the same motor skills showed significance in both gold standard and field-based measures models, coefficients of sex, LC, and OC in the field-based measures model were lower than those of the gold standard model except for LC in the model using maximum speed.

Discussion

Our study explored differences in the associations among motor competence, health-related fitness and physical activity in children using gold standard and field-based measures. Consistent with our hypothesis, we found that associations between motor competence and health-related fitness and physical activity were stronger for the gold standard, compared with the field-based measures. However, the differences between the measurement methods employed to assess aerobic fitness were small. To the best of our knowledge, this is the first comparative study to examine the associations between motor competence and health-related fitness and physical activity using gold standard and field-based measures. Because many of the previous studies used field-based measures, obtained outcomes may confound the association. Therefore, our results provide novel insights into the associations between motor competence and health-related variables and emphasise the use of adequate measurement methods.

BMI showed a very small relationship despite %BF showing a moderate relationship and there were significant differences in the correlation coefficient between BMI and %BF, which supports the hypothesis of V. P. Lopes et al. (2012) that %BF provides a more accurate picture of the relationship. Our findings suggest BMI is not an appropriate measure for assessing the relationship between weight status and motor competence in youth. One reason for this may be the difference in the reliability of assessing weight status. BMI has been used as one of the useful variables to assess body weight status and as a screening test in large populations but does not accurately assess body composition (Castro-Piñero et al., 2010; Wang, 2004). Liu et al. (2023) pointed out that there was a difference in the outcomes depending on whether BMI or %BF (obtained through bio-impedance analysis, BIA) was used. Specifically, the association with motor competence was higher in the case of % BF. Although DXA might be the best method to measure body composition, it requires more time and labour and has higher associated costs. Therefore, %BF may be a more appropriate field-based measure to assess weight status, as the necessary equipment (weight scale with BIA) is considerably less costly than the equipment required to perform DXA.

Similarly, self-reported physical activity showed a very small relationship even though MVPA showed a moderate relationship; the MVPA model showed a strong association with sex. As with weight status, this may be related to the fact that MVPA can discriminate sex differences compared with self-reported physical activity (Table 1). In contrast, the contribution of motor competence, particularly OC, was similar for MVPA and exercise time (Tables 3 and 4). Robinson et al. (2015) indicated methodological issues in that different types of assessment methods have been used in previous studies. However, there was a small difference between motor competence in both MVPA assessed using an accelerometer and self-reported physical activity if the data was controlled for sex (Tables 3 and 4). This finding may be due to a limitation of using accelerometers with children. Of note, we set strict criteria (more than 10 h of wear time from 7:00 to 21:00 and at least 5 weekdays and 2 weekends) to adopt the data and used a tri-axial accelerometer, which has the potential to assess physical activity more accurately (Tanaka et al., 2007). Therefore, we believed that MVPA was assessed more accurately in this study than previous studies. However, human movements are complex and are sometimes stationary like throwing, catching, and bouncing; hence the accelerometer may not be able to accurately assess the activities' intensity and type. Previous studies revealed that accelerometers could not assess the intensity of object control activities (Evenson et al., 2008; Sacko et al., 2019). To resolve this problem, we used the tri-axial accelerometer, which has an algorism separating locomotive from non-locomotive activities including some ball activities (Ohkawara et al., 2011; Hikihara et al., 2014, 2021). This accelerometer may estimate the intensity of movement but not recognise the type of movement.

VO_2peak and maximum speed from the multistage fitness resulted in similar R^2 values. However, the standardised regression coefficient of LC in the maximum speed model was higher than the VO_2peak model. This may be attributed to differences in the aerobic fitness assessment methods. VO_2peak represents "physiological capacity", while maximum speed represents "running performance". Hulteen et al. (2020) observed a significant relationship between LC (process–oriented measure) and running time (product–oriented measure) in 6 – 7-year-old children ($r = –0.45$ to $– 0.63$), which indicates that children who run fast exhibit a better running form. The aerobic fitness was measured using the maximal increment protocol. As this protocol increases the load progressively, we regarded the maximum speed in treadmill running as laps or maximum speed in the multistage fitness test. For these reasons, LC might have a greater contribution to maximum speed than VO_2peak. However, both VO_2peak and maximum speed were obtained from the same test, which may be one of the reasons for the small difference; it needs to be verified whether the same results can be obtained in a more field-oriented test, such as a 20-metre multistage fitness test.

In our study, we hypothesised that motor competence would predict health-related and physical activity in children. However, it is important to note that the relationship between motor competence and health-related fitness and physical activity is likely to be bi-directional (Stodden et al., 2008). For example, higher levels of physical fitness and activity promote the acquisition of motor competence, while higher levels of weight status hinder the acquisition of motor competence. This reverse direction, although important, is not a key aspect of this study. Incidentally, the results of multiple regression in the reverse direction showed a similar trend (data not shown).

The strength of our study was the use of gold standard methods, and multiple regression analysis revealed that the gold standard showed better associations with motor competence than field-based measures. Therefore, we recommend the use of more valid methods to determine the true relationships. However, our study has some limitations. First, TGMD – 2 was used as the motor competence in this study. As TGMD – 2 assesses only the movement of quality (process-oriented). This test does not assess for stability skills, which is one of the fundamental motor skills. Other tests that assess motor competence quantitatively (product-oriented), such as running time and throwing distance, or a combination of process- and product-oriented tests, such as CAMSA (Longmuir et al., 2017), may yield different results. The gold standard for the assessment of motor competence remains lacking (L. Lopes et al., 2021). Second, our study targeted grade 1 students aged 6–7 years. As motor competence, body composition, aerobic fitness, and physical activity dramatically develop during childhood, the relationships among these variables differ in other age ranges.

Conclusion

We compared the strength of associations among motor competence, weight status, aerobic fitness, and physical activity in Japanese children aged 6 – 7 years using gold standard and field-based measures. We found that field-based measures tended to show lower associations with motor competence than the gold standard, with the exception of aerobic fitness. Although measures based on the gold standard should be the first choice for accurate determination of these associations, the use of field-based measures becomes necessary in the case of large-scale surveillance, in order to reduce total time, labour and associated costs. In such cases, our findings might be useful for variable selection.

BMI is one of the most popular variables for assessing weight status; however, it may not be particularly appropriate to accurately reveal its relationship to other variables, especially to LC. Therefore, researchers should use other variables such as %BF using BIA or skinfold thickness to predict body composition. Maximum speed obtained from the 20-metre multistage fitness test is a commonly used variable for assessing aerobic fitness. As these field-based tests represent endurance running performance, they tend to show higher associations with motor competence, especially LC. Although these field-based tests do not necessarily represent physiological capacity, they may still be suitable to assess the associations with motor competence. Finally, the questionnaire is the easiest method to assess physical activity and has great benefits in terms of providing information about the content of activities. Although the accelerometer is the gold standard, it has some limitations, especially for assessing the type of movement. Although MVPA using an accelerometer showed a higher association than exercise time assessed by the questionnaire, the outcomes were influenced by sex. In cases in which researchers are forced to rely on questionnaires, the data should be separately analysed for each sex. To clarify the role of motor competence in children's health, health-related fitness, especially weight status and physical activity, should be measured using highly precise methods.

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