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Identifying Childhood Movement Profiles and Tracking Physical Activity and Sedentary Time Across One Year

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Abstract

This study identified movement profiles in childhood and tracked longitudinal changes in moderate-to-vigorous physical activity and sedentary time across identified profiles. A sample consisted of 491 Finnish 5th Grade children (girls 275, boys 216; M_{age} = 11.27 ± .32). A latent profile analysis strategy was used to identify homogenous movement profiles that included measures of motor competence, perceived competence, and cardiorespiratory and muscular fitness. To examine a one-year changes in moderate-to-vigorous physical activity and sedentary time among movement profiles, a mixed between-within subjects analysis of variance with Tukey's post hoc -tests was conducted. Results revealed three movement profiles; "At-Risk Movement Profile" "Intermediate Movement Profile" and "Desirable Movement Profile". Results demonstrated that moderate-to-vigorous physical activity among the Intermediate Movement Profile declined across one year ($p < .01$), whereas there was no change in sedentary time. To conclude, results of the study indicated remarkable differences in movement skill and physical fitness variables, and moderate-to-vigorous physical activity engagement between the at-Risk Movement Profile and other two profiles. Special attention should be given to the lowest profile of children to promote their movement capabilities and physical activity engagement. It is noteworthy that At-Risk Movement Profile included children more than one third of the sample.

Keywords: Motor competence, health-related fitness, perceived physical competence, a latent profile analysis

Introduction

Numerous empirical studies have indicated that, in many countries, few children and adolescents meet the physical activity (PA) recommendations of at least 60 minutes of daily moderate-to-vigorous physical activity (MVPA).[1] Additionally, an substantial increase of sedentariness has been reported in youth.[2] These unwanted behavioral trends have unfavorable health consequences[3] (e.g. increasing prevalence of obesity, cardiovascular diseases, type 2 diabetes) and these results can shape child and adolescent behaviors that track into adulthood. Although these negative trends are well reported[1], considerable individual differences in PA patterns have been demonstrated across time.[4] Thus, there is a growing need to identify different movement profiles among children, with a particular focus on vulnerable children, to better understand how and why children's PA and sedentary behaviors change across time. Thus, the aim of this study was, first, to identify movement profiles in childhood, and second, to track a one-year longitudinal change in MVPA and sedentary time (ST) across the identified movement profiles.

Research has shown numerous determinants affect PA behaviors.[5] The conceptual framework of this study is based on the developmental model of Stodden et al.[6] highlighting the predictive of roles of movement skills, i.e., motor competence (MC), perceived competence (PC), and health-related fitness (HRF), impacting PA behavior. Most of these variable-level associations have been supported empirically.[8] However, only two cluster analytic studies that applied a person-oriented strategy to address the individual differences in movement skills have examined the role of MC and PC on PA.[9, 10] These studies identified different movement profiles within samples of children and also revealed that participants having high MC and PC also demonstrated higher levels of self-reported[9] and objectively measured PA engagement[10] than students having low MC and PC.

Although variable-level studies have shown MC to be important determinants of PA, and person-oriented studies have shown different movement profiles to exist in childhood, the following shortcomings warrant this present study. First, previous studies that have examined aspects of the Stodden et al[6] model in isolation,[9,10] has not recognized the interdependence among all variables in the model. For instance, as theorized, it is likely that the relationship between HRF and MC is synergistic across time.

The absence of one of the variables may overestimate the role of another, and thus leads to an incomplete picture. Second, Stodden et al emphasizes that the movement skill – PA relationship evolves across time. This study adds to the current knowledgebase by examining these changes across one-year timespan. Finally, the relative lack of studies employing a person-oriented (cluster analytic) approach, comprehensively targeting the variables in the of Stodden et al.'s[6] developmental model, is an important area of research to be explored. The limited previous research in this area speaks to the importance of this type of analysis. It should be recognized that few previous person-oriented studies using the model have used traditional clustering methods, e.g., Ward and K-mean, which are based on subjective distances between variables rather than objective fit criteria (within-cluster differences are minimized and between-cluster differences maximized).[11] In the current study, we used model-based method of the latent profile analysis (LPA) to overcome this shortcoming. Compared to the traditional cluster analytic techniques, LPA accounts for the dynamic relationships between variables, and more rigorous and objective criteria to determine the number of clusters from the data.[11]

Building on the current knowledge and addressing the shortcomings of the previous studies, the aim of this study was, first, to identify different movement profiles in childhood, and second, to track a one-year longitudinal changes in PA and ST across the identified movement profiles.

Materials and methods

More accurate description of materials and methods section is given in supplementary material

Participants

A total sample included 491 (216 boys and 275 girls; M_{age} = 11.27±.32) Finnish elementary school students from Southern and Central Finland. The first measurement phase was conducted in August/September 2017, and the second phase one year later.

Measurements

Moderate-to-vigorous intensity physical activity and sedentary time. Students' MVPA and ST were assessed using hip-worn ActiGraph wGT3X+ accelerometers.

Perceived competence. Students' PC was assessed using the sport competence dimension of the Physical Self-Perception Profile.[12]

Motor competence. Students' MC was measured using the following product-oriented fundamental movement skill tests; 1) two-legged jumps from side to side test (balance skill)[13] 2) throwing-catching combination test (object control skills)[14]; and 3) 5-leaps test (locomotor skill).[14] The detailed description of the MC measurements is presented in Table 1.[8] The scores of the MC tests were standardized and analyses were performed using Z-scores.

Cardiovascular fitness. Students cardiovascular fitness was evaluated using the 20 meters shuttle run test (PACER).[15] A description of the PACER protocol is given in Table 1.

Muscular fitness. Students' muscular fitness was measured with push-up and curl-up tests.[14] For the analyses, a composite score of muscular fitness was created from the standardized Z-scores. Descriptions of push-up test and curl-up tests are provided in Table 1.

Data Analysis

Descriptive statistics including correlations, means, and standard deviations for the study variables are presented Table 2. To identify student groups with homogenous profiles in MC, PC, muscular fitness, and cardiovascular fitness, a LPA was conducted. To examine MVPA and ST across the baseline and follow-up measures between clusters including girls and boys (gender x cluster membership x time), mixed between-within subjects analysis of variance (ANOVA) with Tukey's post hoc -tests were implemented. The MCAR test for missing values and ANOVA models were performed using SPSS Version 22.0 and LPA models using Mplus Version 8.2.[16]

Results

Preliminary Analysis

A graphical display showed that the data were normally distributed. No significant outliers were detected based on the standardized values (± 3.0). The data comprised 11.6% of missing values out of all 5401 measured values. The Missing Completely at Random (MCAR) test (χ^2 = 269.85, *df* = 223, *p* = .017) indicated differences between data with and without missing values.[17] A closer examination showed that missing values did not represent any special group or school, and thus, the missing data were expected to be missing at random (MAR). Missing values were not imputed, but estimated using full information maximum likelihood procedures, which has been shown to produce unbiased parameter estimates and standard errors under MAR conditions.[18]

Descriptive Statistics

Correlation coefficients, means, and standard deviations of the study variables, and differences between girls and boys were analyzed (Table 2). The strongest positive correlations were found between 5-jump and cardiovascular fitness variables in both girls and boys. In turn, the strongest negative correlations were detected between MVPA T1 and ST T1, in other words, the higher MVPA minutes, the lower sedentary minutes and vice versa. On average, students had relatively high PC; however, only boys achieved the current guidelines of 60 minutes of MVPA per day at the baseline measurement. Specifically, boys demonstrated higher PC, throw-and-catch skill, cardiovascular fitness, MVPA at T0 and T1 scores than girls. Girls demonstrated higher side-to-side jump, push-up, curl-up, and sedentary T0 scores than boys.

Latent profile analysis

The results of LPA including MC, PC, muscular fitness, and cardiovascular fitness were examined (Supplement table 1). The AIC, BIC, and SSA-BIC indices decreased when the number of groups increased, but only marginally after the three group-solution. The *p* values of the LMR for K versus K-1 classes were also non-significant for each higher group solutions with an exception with six clusters. The three-group solution was significantly better than the two-group solution, but the four-group solution was not better than the three-group solution. Based on all indices, a three-group solution was considered as most justifiable. Means and standard deviations of the study variables for each three cluster are presented in Table 3.

Latent cluster 1 was labelled as the "*At-Risk Movement Profile*". Students of this group reported the lowest MC, PC and muscular/cardiovascular fitness scores. This profile comprised 113 girls and 72 boys, nearly 38% of the total sample. Latent cluster 2 represented 49% (138 girls, 104 boys) of the total sample. This group was named as the "*Intermediate Movement Profile*". Specifically, students of this profile reported moderate MC, PC, and muscular and cardiovascular fitness scores. Latent cluster 3 was labelled as the "*Desirable Movement Profile*". This profile represented students who had the highest MC, PC and muscular and cardiovascular fitness scores among the three cluster profiles. This group comprised 13% (24 girls, 40 boys) of the total sample.

Mixed between-within subjects ANOVA

The mixed ANOVA models were conducted to compare the gender-specific differences in MVPA and ST scores between three identified profiles across two time points (gender x cluster membership x time). No violations regarding the variances between clusters were detected in MVPA nor ST scores. The results showed a statistically significant cluster membership x time interaction in MVPA minutes ($F(2, 241) = 4.636$, $p = .003$, $\mu_p = .037$), indicating that MVPA minutes developed in a different way between groups over time. MVPA minutes of At-Risk Movement and Desirable Movement Profiles remained stable over time, whereas MVPA minutes of Intermediate Movement Profiles students declined across the measurements ($p < .01$). Tukey's post hoc tests revealed significant differences in MVPA minutes between At-Risk and Intermediate Movement Profiles groups ($p < .001$), Intermediate Movement and Desirable Movement Profiles ($p < .001$), and At-Risk Movement and Desirable Movement Profiles ($p < .001$), revealing that MVPA minutes of At-Risk Movement Profile were lower than Intermediate Movement Profile and Desirable Movement Profile and Intermediate Movement Profile had lower minutes than Desirable Movement Profile across the baseline and follow-up measures (Figure 1).

The mixed ANOVA model including sedentary time as an independent variable showed no significant gender x cluster membership x time ($F(2, 241) = .740$, $p = .478$, $\mu_p = .006$), gender x time ($F(1, 241) = 1.156$, $p = .283$, $\mu_p = .005$), cluster membership x time ($F(2, 241) = .326$, $p = .722$, $\mu_p = .003$) interactions, nor significant main effects for the baseline and follow-up measures ($F(1, 241) = 2.395$, $p = .123$, $\mu_p = .010$), indicating that ST remained stable in all groups across the baseline and follow-up measures. However, the Tukey post hoc test revealed significant differences in sedentary time between At-Risk Movement Profile and Intermediate Movement Profile ($p < .001$), Intermediate Movement Profile and Desirable Movement Profile ($p < .01$), and At-Risk Movement Profile and Desirable Movement Profile ($p < .001$). Sedentary time of At-Risk Movement Profile was higher than Intermediate and Desirable Movement Profiles and Intermediate Movement Profile had higher minutes than Desirable Movement Profile across the measurements (Figure 2).

Discussion

This study aimed, first, to identify movement profiles in childhood, and second, to track longitudinal changes in PA and ST across the identified movement profiles. This study revealed three movement profiles; the Intermediate Movement Profile was the largest group including almost half of the participants, the At-Risk Profile included more than one third of the sample, whereas the Desirable Movement Profile was the smallest, including only 13 % of the participants.

Results of the study indicated that there were remarkable differences in measured variables and MVPA engagement between the At-Risk Movement Profile and other two profiles. For example, in 20-meter PACER test the students in the Desirable Movement Profile ran three times more laps and the Intermediate Movement Profile two times more laps than the students in the At-Risk Movement Profile respectively. It is noteworthy, that one third of the students did not reach healthy fitness zone benchmark for the cardiovascular fitness test set by Fitnessgram.[19] These results are alarming because it is evident that sufficient cardiovascular fitness in childhood affects health and cardiovascular risk factors in adulthood.[20] Similar differences among movement profiles were also found in muscular fitness. The At-Risk Profile demonstrated much lower muscular fitness than the other two profiles as evidenced in their results in the push-up and curl-up tests. The mean for the lowest group in the curl-up test was 15 repetitions narrowly meeting the healthy fitness zone.[19] This is also an important finding because previous research has demonstrated that muscular fitness has many positive health effects in childhood and adolescence.[21] Additionally, although this study did not reveal cluster differences in the development of PA engagement from time 0 to time 1, it should be recognized that previous empirical studies have demonstrated that higher levels of health-related fitness in childhood is positively associated with PA later in adolescence[22] and adulthood.[23]

Results of this study also indicated that the At-Risk Movement Profile had significantly lower MC than other two profiles. The development of a broad foundation of motor skills is suggested to promote participation in a wide variety of lifetime physical activities.[6,7] Empirical studies have supported this assumption by demonstrating that sufficient MC in childhood is positively linked with PA engagement from childhood to adolescence[24] and from adolescence to early adulthood.[22] In addition, it has been suggested that an MC proficiency barrier may exist[25], which may impact adequate participation in PA and fitness development into adulthood.[25]

Results of this study also demonstrated that there were large differences in MVPA time among clusters. More specifically, the At-Risk Movement Profile had 25 – 30 minutes less MVPA than the Desirable Movement Profile. Results also showed that only 17 % (T0) and 24 % (T1) of the students in the At-Risk Movement Profile achieved recommended 60 minutes of daily MVPA. These are much lower proportions comparing with the Desirable Movement Profile in which more than two thirds of the students reached recommendation. It should also be recognized that differences in MVPA and ST among profiles were rather stable across time. These findings suggest that the differences in MVPA and ST may already have been established earlier in development, and once emerged, differences in these behavioral patterns remain stable.

It is important to note that the At-risk Movement Profile included more than one third of the sample, suggesting that special attention should be given to this group of children, with resources to identify and intervene to promote their physical (i.e., MC and fitness) and self-concept development capabilities for future PA.

Results of this study also indicated differences in the development of MVPA among the three identified subpopulations. MVPA minutes in the Desirable and the At-Risk Movement Profiles remained stable over time, whereas MVPA of the students in the Intermediate Movement Profile declined across time. Although this group of students had relatively good fitness (met healthy fitness zone for cardiovascular and muscular) and on average they met the 60 minutes of daily MVPA recommendation, the declining trend is a concern. If the declining trend for these students continues, it is likely that further development of their physical fitness will decline due to lower activity levels. School physical education is a valuable venue to promote students' MVPA levels because it has many cognitive, affective and behavioral goals to promote students' physically active lifestyle and physical activity regularly reaches the whole age cohort of children.[26]

This study has several strengths including of all aspects of the Stodden et al's[6] developmental model in the analysis, objective measurements, longitudinal design, and relative large sample size. However, this study is not free from limitations. Firstly, it should be recognized that we measured MC only using product-oriented measures. Because of the large sample size of the project and many collected measures, it was not possible to use process-oriented assessments to evaluate students' MC. Additionally, we did not have resources to measure participants' growth and maturational levels which may be one factor behind the results[27] In the future, it would be beneficial to track relationships among MC, PC, HRF and PA over longer time period. Similarities in the change patterns between variables would indicate that there may be causal relationship between variables. In addition, it would be worthwhile to investigate whether the profile memberships are stable across time. Stability would highlight the importance of detecting and treating a lack of MC early, since these deficiencies may track to adulthood.

Perspectives

Irregular PA and high amounts of daily sedentariness can shape childhood and adolescence into vulnerable adulthood. Therefore, it is important to study antecedents of these unhealthy behavioral trends, especially in childhood. The study revealed three rather homogeneous movement profiles linking multiple physical variables that differed substantially across profiles. This type of analysis provides a more in-depth analysis of the linkage between multiple variables that are critical to healthy lifestyle development and provides an overall picture of the need for more holistic intervention strategies that focus on multiple physical and self-concept domains. As one third of the sample and demonstrated low MC, HRF, PA and high ST, it speaks to the continuing issue of secular decline in all these variables.

Authors of this manuscript have no conflict of interest to declare.

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Table. 1 Motor competence and physical fitness tests (Table originally published by Jaakkola et al.[8]).

Tests	Method	Scoring
Motor competence		
5-leaps test (leaping skill).	Complete five leaps, beginning and finishing with legs in a parallel position.	The distance from the starting to the finish position (measured from heel of the nearest foot)
The throwing-catching combination test (throwing and catching skills).	Throw a tennis ball to a 1.5 x 1.5m -sized target area 90cm above the floor level. Throwing distance is 7 and 8m, girls and boys, respectively. Students had 20 attempts to throw the ball behind the marked line, hit the target area, and catch the ball after one bounce.	The number of correctly performed throwing-catching combinations.
Two-legged jumping from side to side test (dynamic balance and agility).	Jump consecutively 15s over a small wooden beam (60 × 4 × 2cm) from one side to another. Jumps are performed legs in a parallel position.	The number of jumps over wooden beam in 15s. The test is conducted twice and the total score is the sum of these two attempts.
Physical fitness		
20 meters shuttle run test (cardiovascular endurance).	Run continuously between two lines 20m apart following the cadence. The pace of the cadence increases at each level (Initial running velocity of 8.5 km/hr, and increasing by 0.5	Number of shuttles reached before participant is unable to keep on pace.

	km/hr each minute).	
Push-up tests (upper body muscular endurance/strength).	Boys' version: Start in up position where: 1) hands and toes touch floor; 2) body and legs are in a straight line; 3) the arms are at shoulder width apart; 4) feet are slightly apart. Keeping back and knees straight lower body until there is a 90-degree angle in elbows (with the upper arms parallel to the floor). Girls' version: Start in up position where: 1) hands and knees touch floor; 2) body and thighs are in a straight line; 3) the arms are at shoulder width apart; 4) knees are slightly apart. Keeping back and thighs straight lower body until there is a 90-degree angle in elbows (with the upper arms parallel to the floor).	Number of correctly completed push-ups in 60 seconds.
Curl-up test (abdominal muscles muscular endurance/strength).	Start by lying on your back and keep: 1) knees bent at 100 degrees; 2) legs slightly apart; 3) both feet on floor; 4) arms straight and parallel to the trunk with palms of hands resting on the floor; 5) stretch fingers out and keep head on floor. The measuring tape is located under participant's legs so that their fingertips are just resting on the nearest edge of tape. Keep heels	Number of correctly completed curl-ups reached before participant is unable to keep on pace (coming from tape).

	on mat and curl up slowly. While curling up fingers slide across the measuring tape until fingertips reach the other side of tape. After that curl back down until head touches the floor. Performance rhythm comes from the tape.	

Table 2. Correlation coefficients, means, standard deviations, and gender differences in the study variables.

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M	SD	W_t
1. Perceived	♀		.26***	.21***	.38***	.31***	.19**	.39***	.24***	.19*	-.18**	-.25**	3.36	.80	.28(.08)***
competence T0	♂		.36***	.38***	.36***	.28***	.10	.42***	.22**	.11	-.11	-.03	3.64	.88	
2.Throwing-	♀			.41***	.43***	.30***	.25***	.45***	.24***	.17*	-.11	-.15	9.63	5.04	2.93(.45)***
catching T0	♂			.53***	.51***	.37***	.26***	.55***	.41***	.31**	-.27***	-.27***	12.56	4.81	
3. Side-to-side jump	♀				.49***	.49***	.42***	.49***	.26***	.23**	-.16**	-.20*	38.50	6.45	-1.93(.60)***
T0	♂				.61***	.50***	.30***	.58***	.36***	.29**	-.23**	-.12	36.57	6.50	
4. 5-leaps T0	♀					.41***	.50***	.60***	.28***	.23**	-.15*	-.21**	7.72	.91	.03(08)
	♂					.47***	.33***	.61***	.38***	.40***	-.23**	-.23*	7.76	.89	
5. Push-up T0	♀						.36***	.46***	.25***	.26**	-.13*	-.23**	27.24	11.54	-9.10(1.08)***
	♂						.40***	.56***	.35***	.25**	-.20**	-.19*	18.14	11.66	
6. Curl-up T0	♀							.36***	.21**	.13	-.14*	-.21**	41.28	23.34	-3.13(2.08)
	♂							.30***	.22**	.25**	-.17*	-.12	38.16	21.78	
7. 20 meters shuttle run	♀								.37***	.28***	-.22***	-.28**	33.12	15.61	7.46(1.70)***
T0	♂								.54***	.49***	-.30***	-.32***	40.58	19.91	
8. MVPA T0	♀									.55***	-.76***	-.37***	54.90	21.05	9.13(2.18)***
	♂									.53***	-.70***	-.47***	64.03	24.34	
9. MVPA T1	♀										-.48***	-.66***	51.89	19.20	7.41(2.50)**

	♂	$-.30^{**}$	$-.72^{***}$	59.29	22.20	
10. Sedentary time T0	♀		$.55^{***}$	689.93	52.36	-
	♂		$.53^{***}$	673.08	53.63	$16.84(5.03)^{***}$
11. Sedentary time T1	♀		-	692.46	52.21	-8.65(6.70)
	♂		-	683.82	59.06	

Note 1. Girls (♀), boys (♂), mean (M), standard deviation (SD), Wald's test (W_t), standard errors in the parentheses.

Note 2. ***p < .001, **p < .01, *p < .05.

Table 3. Means and standard deviations (in the parentheses) of the study variables by clusters.

	"At-Risk Movement Profile" N = 185	"Intermediate Movement Profile" N = 242	"Desirable Movement Profile" N = 64
Perceived competence	3.01 (.69)	3.63 (.74)	4.22 (.85)
Throwing-catching combination test	7.20 (4.49)	12.55 (4.10)	15.64 (2.92)
Side-to-side jump test	32.92 (5.31)	39.54 (5.19)	44.06 (4.98)
5-leaps test	7.03 (.63)	8.01 (.70)	8.74 (.68)
Push-up test	15.91 (9.49)	25.89 (11.46)	33.38 (12.01)
Curl-up test	29.40 (19.00)	43.21 (22.10)	56.67 (20.59)
20 meters shuttle run test	19.67 (7.82)	41.59 (10.22)	65.89 (9.24)
MVPA T0	45.91 (16.90)	63.09 (20.87)	77.83 (25.30)
MVPA T1	47.39 (18.59)	56.42 (19.64)	72.66 (20.68)
Sedentary time T0	702.08 (46.88)	675.34 (53.03)	657.62 (55.48)
Sedentary time T1	706.21 (55.87)	684.88 (52.17)	652.25 (46.10)
% to achieve 60 min of daily MVPA T0	16.9%	54.7%	75.8%
% to achieve 60 min of daily MVPA T1	23.8%	38.6%	68.6%

Figure captions

Figure 1. Daily accelerometer-based moderate-to-vigorous physical activity minutes (Y-axis) by movement profiles at T0 and T1 (X-axis).

Cluster 1 = At-Risk Movement Profile

Cluster 2 = Intermediate Movement Profile

Cluster 3 = Desirable Movement Profile

Figure. 2. Daily accelerometer-based sedentary time minutes (Y-axis) by movement profiles at T0 and T1 (X-axis).

Cluster 1 = At-Risk Movement Profile

Cluster 2 = Intermediate Movement Profile

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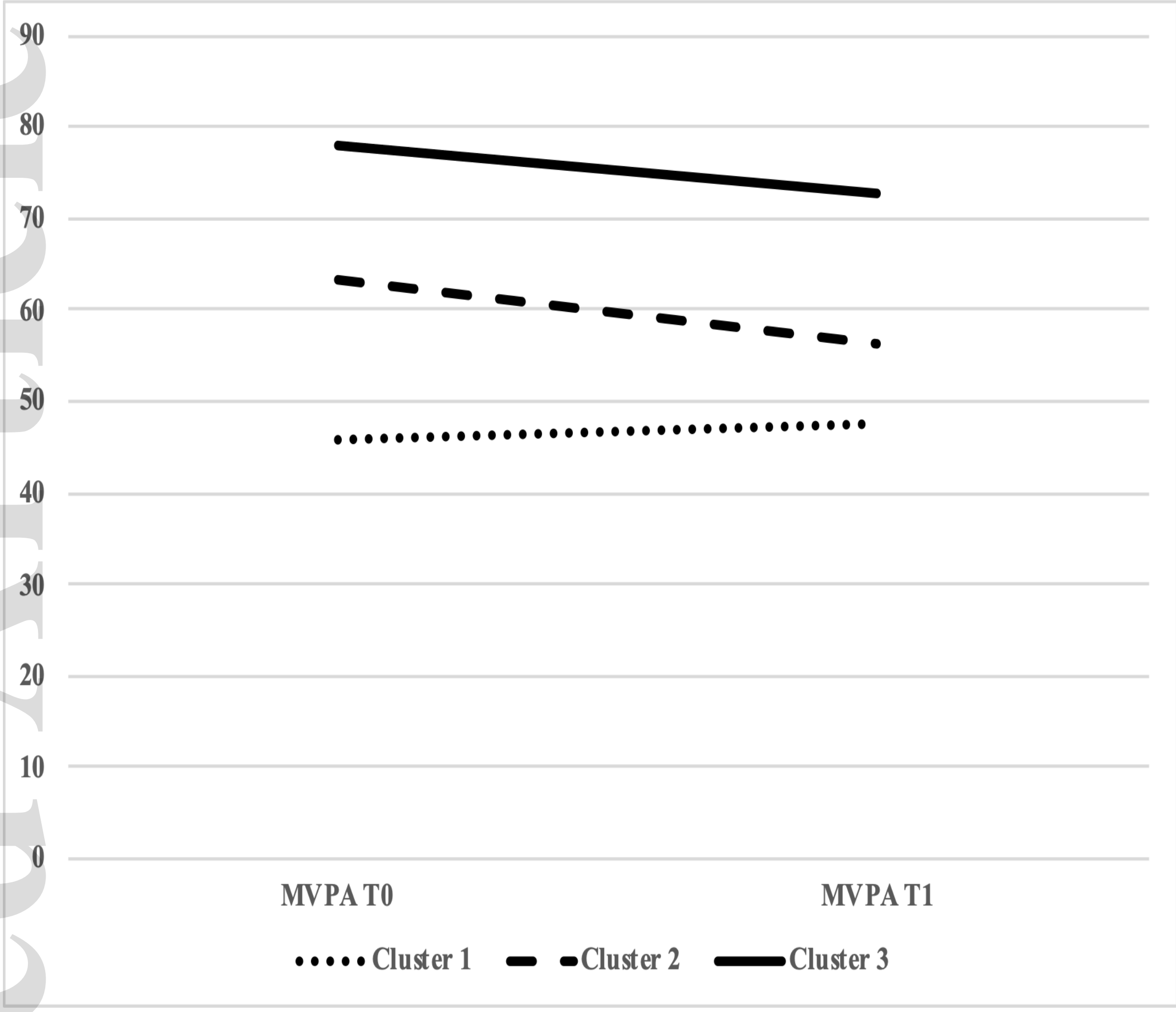

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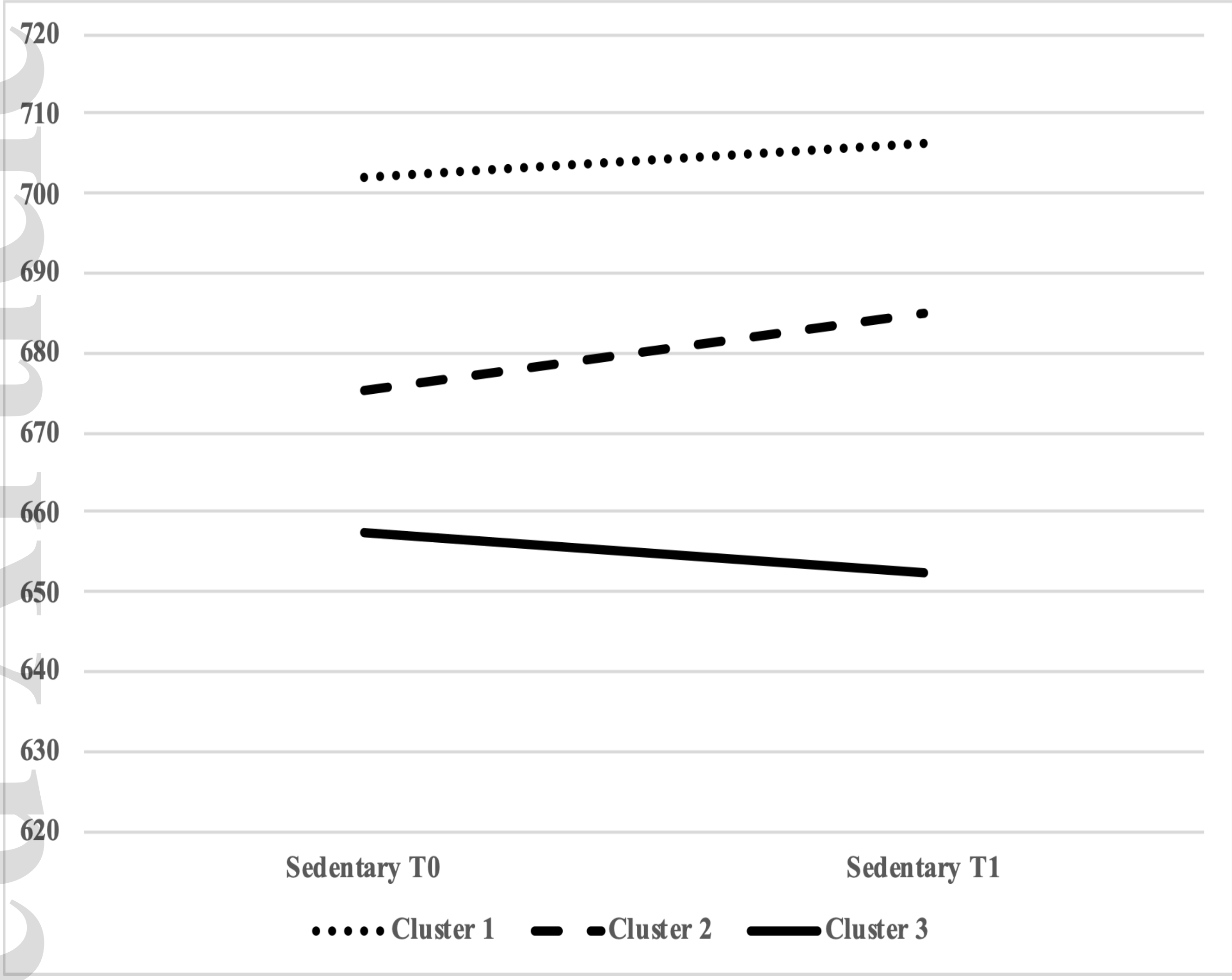

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