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Misalignment or Motivation? A Cluster Analysis Approach to Understanding Young Adolescent Physical Activity Trajectories in Summer Care Programs

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Abstract: Physical activity (PA) decreases during summer months, potentially leading to accelerated weight gain and increased depressive symptoms in adolescents. Summer care programs offer opportunities for PA promotion but understanding how different groups (based on initial perceived and objectively measured PA) respond to these programs is crucial for developing focused interventions. Adolescents (n = 47; mean age = 11.0 years; 51.1% female) who participated in an 8-week summer program wore ActiGraph GT9X accelerometers to measure moderate-to-vigorous physical activity (MVPA) at the beginning and end of the program. Self-reported PA was assessed using the Health Behavior in School-Aged Children survey. Both measures were then transformed into respective z-scores. K-means cluster analysis was performed to identify distinct groups based on device-measured and perceived PA at the beginning of summer. Changes in MVPA were compared across clusters using one-way ANOVA and post hoc Tukey's HSD tests. Three clusters were identified: "High Accuracy Actives" (n = 17), "Underestimators" (n = 22), and "Overestimators" (n = 8). "Overestimators" showed the largest mean increase in MVPA (30.63 min/day), followed by "Underestimators" (17.76 min/day). "High Accuracy Actives" experienced a mean decrease in MVPA (−7.69 min/day). ANOVA revealed significant differences in MVPA change between clusters ($F(2,44) = 4.93$, $p = 0.01$). Summer care programs can positively impact adolescent PA, particularly for those who initially underestimate or overestimate their activity levels. However, strategies are needed to prevent declines among initially highly active participants. For example, adolescents who underestimate their activity levels may benefit from interventions focused on building self-efficacy and providing positive feedback, while those who overestimate might require educational components about PA guidelines and self-monitoring techniques.

Keywords: physical activity; latent class profiles; summer programs; youth

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1. Introduction

Physical activity (PA) plays a crucial role in adolescent health and development, offering numerous benefits including improved cardiovascular fitness, bone health, psychological well-being, and reduced risk of obesity [1,2]. Despite recommendations that children and adolescents engage in at least 60 min of moderate-to-vigorous PA (MVPA) daily [2], only a small percentage (22% of boys and 9% of girls) meet these guidelines. Specifically, adolescent girls often report lower participation in PA compared to boys [3]. Insufficient PA is concerning given its potential long-term health implications and the increased risk of physical inactivity persisting into adulthood [4].

The summer months present both challenges and opportunities for adolescent PA. Research has consistently shown that PA levels tend to decrease during summer break compared to the school year, potentially leading to increased depressive symptoms, a decline in mental health, accelerated weight gain, and disrupted fitness trajectories [5–8]. Summer care programs can promote PA during this critical period by providing structured opportunities for PA, access to facilities, and social environments conducive to active behaviors [9,10]. Summer programs in the United States can vary dramatically but are typically community-level resources that offer childcare for families during the summer but also engage families throughout the school year with afterschool enrichment programs. In the summer, these programs often provide full-day supervision involving a variety of activities, including programmed PA opportunities, free play, crafts, and other activities. Studies have shown that children can accumulate nearly 90 min of MVPA on average while attending summer care programs [9,11]. These settings are also conduits for peer group norms or social interaction and social influence on health and health behaviors among adolescents, specifically PA [12–15]. However, understanding of how different groups of adolescents respond to and benefit from these programs is limited.

An essential consideration in understanding adolescent PA behaviors is the potential discrepancy between perceived and objective measures of activity and how these measures may influence PA engagement. Self-perceived PA is influenced by various factors, including social norms, self-efficacy, and cognitive biases [16–18]. When this perception misaligns with objectively measured activity levels, it may create a state of cognitive dissonance—a psychological discomfort arising from holding contradictory beliefs or attitudes [19]. Such dissonance may strongly motivate behavior change [20]. For instance, adolescents who perceive themselves as highly active but receive objective feedback indicating low activity levels may be motivated to increase their PA to align their behavior with their self-perception. Conversely, those who underestimate their activity levels might benefit from positive reinforcement to boost their self-efficacy and maintain their behavior [21]. Understanding these perceptual discrepancies is crucial for developing focused interventions and maximizing their impact on PA behaviors. For example, educating adolescents about actual PA guidelines and helping them accurately assess their activity levels could leverage cognitive dissonance to promote behavior change [22]. Moreover, examining the factors associated with over- or underestimation of PA can provide insights into potential barriers or facilitators to activity that may not be captured by objective measures alone [23]. By exploring both perceived and objective PA, researchers can gain a more comprehensive understanding of adolescent activity patterns and develop more nuanced, psychologically informed strategies for PA promotion in summer care programs.

To better understand the complex relationship between perceived and objective PA levels among adolescents, researchers can employ cluster analysis techniques. This statistical approach can identify distinct subgroups within a population based on multiple characteristics [23,24]. In the context of adolescent PA, cluster analysis can reveal patterns in how perceived and objective activity levels interact, potentially uncovering unique groups. These groups can provide valuable insights into which adolescent subgroups might derive the greatest benefit from summer care programs and which may need tailored interventions to address discrepancies between their perceptions and actual behaviors. The purpose of this study is to utilize cluster analysis to identify distinct adolescent groups based on the relationship between their perceived and objectively measured MVPA levels in the context of a summer care program. By examining these patterns, we aim to uncover subgroups of adolescents who may respond differently to summer care program environments and potentially require tailored interventions to optimize their PA outcomes. Specifically, this research seeks to identify clusters of adolescents with similar patterns of perceived versus objective MVPA and examine how these clusters may differ in their PA trajectories across the summer. Through this analysis, we hope to provide insights that can inform the development of more focused and effective PA promotion strategies within summer care programs, addressing the unique needs of different adolescent groups and potentially improving the overall impact of these programs on youth PA behaviors. For example, adolescents who underestimate their activity levels may benefit from interventions focused on building self-efficacy and providing positive feedback, while those who overestimate might require educational components about PA guidelines and self-monitoring techniques.

2. Materials and Methods

2.1. Participants

The research team recruited participants aged 10 to 14 years from a summer program at a Boys & Girls Club in central Texas. Data collection occurred across four days at the beginning and end of the 8-week summer program in 2023. Evaluation weeks were chosen to be as close to the start and end of the summer program while still representing "normal" programming, as many programs have orientation week and a modified last week of programming. No change in programming was Surveys were administered individually to participants using a computer in a private room at the club facility during regular operating hours. A member of the research team was present to facilitate the survey process. Parents received information about the study and were assured their child's participation was voluntary, with the option to withdraw at any time without affecting their involvement in the summer program. Prior to each survey administration, adolescents had provided written assent, confirming their willingness to participate. The study protocol underwent review and received approval from the Institutional Review Board at the researchers' affiliated university before the start of the study.

2.2. Measures

2.2.1. Device-Measured Physical Activity

To assess PA objectively, participants wore ActiGraph GT9X accelerometers (ActiGraph, Pensacola, FL, USA). on the non-dominant wrist for four days while at the program during the evaluation periods. Previous studies have shown that the wrist is a preferred location for children as it is easier for them to wear while engaging in PA [25]. The accelerometers captured raw data at a frequency of 30 Hz, which was subsequently analyzed using advanced processing techniques. Data analysis employed a machine learning approach, specifically a random forest classifier, which has been validated for use with school-aged youth [26,27]. This algorithm categorizes various activities based on patterns in the acceleration data, distinguishing between sedentary behaviors, light activities, ambulatory movements, and more vigorous forms of PA [26,27]. For each participant, MVPA was quantified by summing the time spent in walking, running, and other moderate to vigorous intensity activities. The final MVPA measure represented the average daily time spent in these activities, calculated across all wear days. Participants were included if they had at least two wear days in each time period.

2.2.2. Self-Reported Physical Activity

Self-reported PA was assessed using a validated item from the Health Behavior in School-Aged Children (HBSC) survey [28]. Participants were asked to report the number of hours they engaged in PA during a typical week, with response options on a 5-point Likert scale ranging from “none” to “about 7 h per week or more”. This measure has demonstrated acceptable test–retest reliability in previous studies with adolescent populations and provides a general indication of perceived weekly PA levels [28].

2.3. Data Analysis

First, PA measures were transformed into their respective z-scores. To identify distinct groups based on device-measured and perceived PA at the beginning of the summer, a k-means cluster analysis was performed using the package kmeans in R (version 3.6.2). This algorithm partitions n observations into k clusters, where each observation belongs to the cluster with the nearest mean (cluster centroid), using Euclidean distance as the default metric for measuring proximity between data points and centroids [29]. To decide on the optimal number of clusters, three methods were employed: (1) elbow method: this method involves plotting the within-cluster sum of squares against the number of clusters and identifying the “elbow” point where the rate of decrease sharply slows [30]; (2) silhouette analysis: this metric evaluates the consistency within clusters, providing a measure of how similar an object is to its own cluster compared to others. Higher silhouette scores indicate better clustering [31]; and (3) gap statistics: this method compares the total within intra-cluster variation for different numbers of clusters with their expected values under the null reference distribution of the data [32]. A three-cluster solution was selected based on these criteria and validated using visualization techniques. Cluster one, labeled “High Accuracy Actives”, was characterized by high levels of both device-measured and perceived PA. Cluster two, labeled “Underestimators”, exhibited medium device-measured PA but low perceived PA. Cluster three, labeled “Overestimators”, showed low device-measured PA but medium perceived PA. To compare MVPA trajectories over the summer, a change score was created for each adolescent corresponding to their change in minutes of MVPA between the beginning and end of summer. One-way Analysis of Variance (ANOVA) was conducted based on these clusters for change scores. When significant differences were detected, post hoc comparisons using Tukey’s HSD test were performed to identify specific between-group differences. All statistical tests were performed in R (version 3.6.2).

3. Results

In total, 47 adolescents participated in the data collection process for this study (n = 47; M = 11.0 years old; SD = 1.3; 51.1% female). Pairwise comparisons showed MVPA was significantly higher at the end of summer (M = 62.7, SD = 26.6) compared to the start of summer (M = 53.7, SD = 17.0)—a mean difference of 9.04 min per day (min/day). There was a significant main effect for time, $F(1,46) = 4.92$, $p = 0.03$, partial $\eta^2 = 0.06$. See Table 1 for more demographic information on the total sample.

Table 1. Sample demographics.

Variable	n	%	Time 1 Mean (SD)	Time 2 Mean (SD)
Sex				
Girl	24	51.1%		
Boy	23	48.9%		
Grade Level				
4th	1	2.1%		
5th	20	42.6%		
6th	15	31.9%		
7th	6	12.8%		
8th	2	4.3%		
9th	3	6.4%		

Table 1. *Cont.*

Variable	n	%	Time 1 Mean (SD)	Time 2 Mean (SD)
Race				
American Indian or Alaska Native	3	6.4%		
Black or African American	19	40.4%		
White	22	46.8%		
Mixed race	3	6.4%		
Ethnicity				
Hispanic	21	44.7%		
Non-Hispanic	26	55.3%		
Age (years)			11.00 (1.27)	11.05 (1.27)
MVPA (min/day)			53.7 (17.0)	62.7 (26.6)

Note: SD: standard deviation; MVPA: moderate-to-vigorous physical activity; Time 1: at the beginning of the program; Time 2: at the end of the program.

Cluster Trajectories

The sample was divided into three clusters based on perceived and device-measured PA. The "High Accuracy Actives" cluster (n = 17) showed the highest initial device-measured MVPA (M = 64.88 min/day, SD = 18.85) and the highest self-reported PA frequency (M = 4.10, SD = 0.87). However, this cluster experienced a mean decrease in MVPA over time (M = −7.69 min/day, SD = 31.80). The "Underestimators" cluster (n = 22) began with moderate levels of MVPA (M = 47.14 min/day, SD = 9.38) but reported the lowest self-reported PA frequency (M = 1.64, SD = 1.00). Despite this, the "Underestimators" cluster demonstrated a mean increase of 17.76 min of daily MVPA (SD = 29.12). "Overestimators" (n = 8) started with the lowest MVPA (M = 36.49 min/day, SD = 10.33) and moderate self-reported PA frequency (M = 3.13, SD = 1.25) but showed the largest mean increase in MVPA (M = 30.63 min/day, SD = 39.04). See Figure 1 for a display of cluster means at the start of summer.

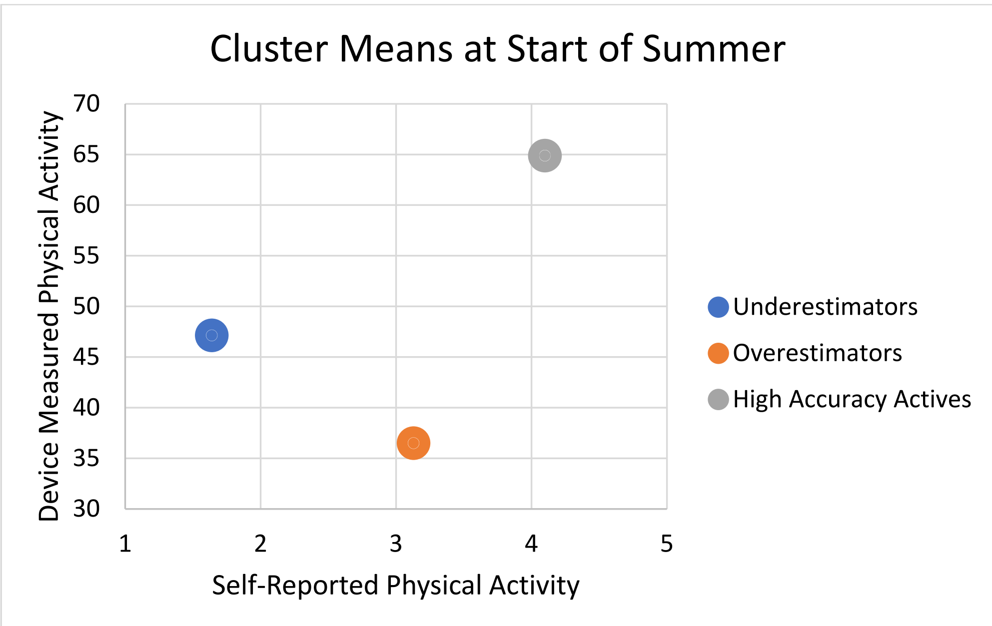

Figure 1. Self-reported and device-measured physical activity cluster means at the start of summer.

A one-way ANOVA revealed a significant effect of perceived PA cluster membership on change in MVPA, F(2,44) = 4.93, $p = 0.01$. Post hoc comparisons using Tukey's HSD test indicated that the mean MVPA change for the "Underestimators" cluster (M = 25.45, 95% confidence intervals [CI, 0.50, 50.41]) was significantly higher than the "High Accuracy Actives" cluster ($p = 0.04$). Similarly, "Overestimators" showed a significantly greater MVPA change (M = 38.32, 95% CI [5.19, 71.45]) compared to the "High Accuracy Actives" cluster ($p = 0.02$), while the difference between the "Underestimators" and "Overestimators" clusters was not statistically significant ($p = 0.59$). Figure 2 displays the visual MVPA trajectories of these clusters across the summer.

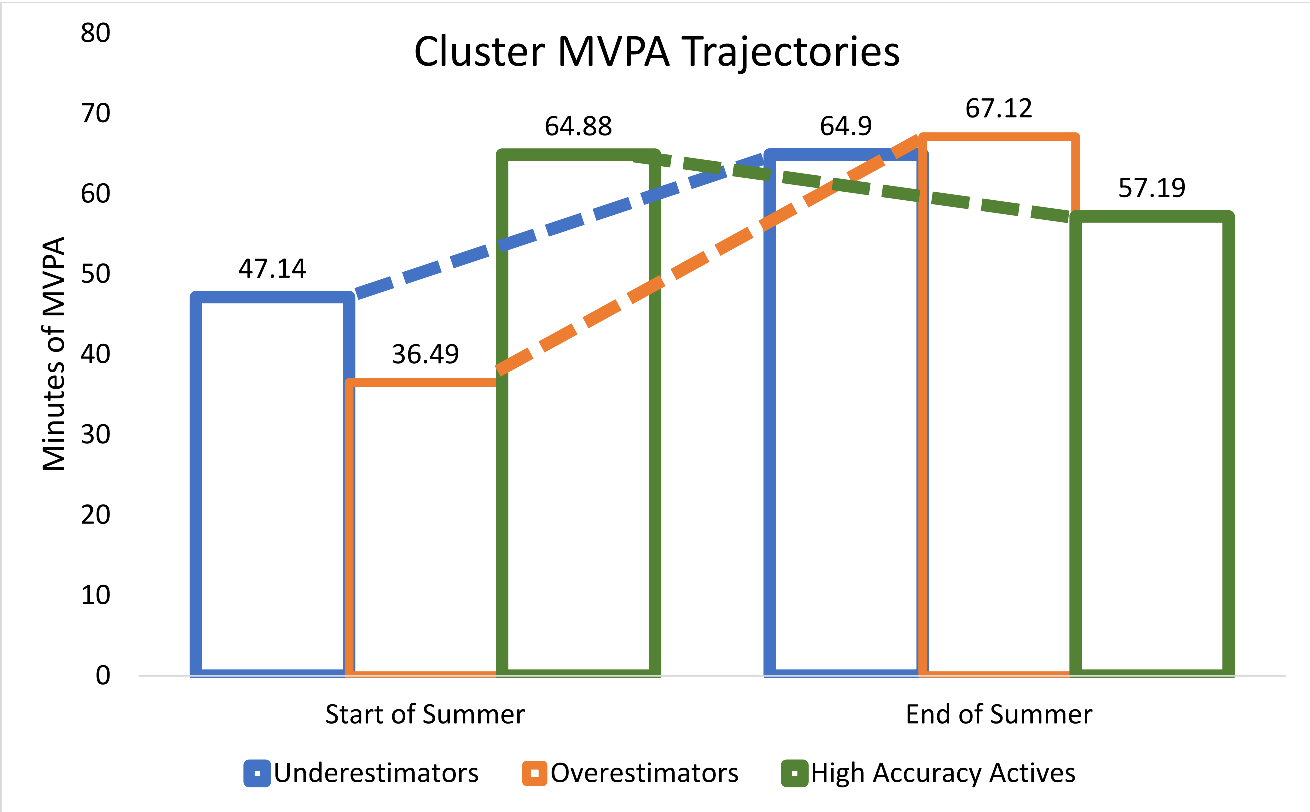

Figure 2. Cluster trajectories in moderate-to-vigorous physical activity across the summer.

4. Discussion

This study aimed to identify distinct groups of adolescents based on the relationship between their perceived and objectively measured MVPA levels in the context of a summer care program. Our objectives were to identify clusters of adolescents with similar patterns and examine how these clusters differed in their PA trajectories across the summer. By employing cluster analysis, we identified three distinct groups: "High Accuracy Actives", "Underestimators", and "Overestimators", each demonstrating unique patterns of perceived and actual PA behaviors.

The finding that the "Overestimators" cluster, characterized by low initial device-measured MVPA but moderate self-reported PA, showed the largest mean increase in MVPA over the summer program has important implications. This outcome aligns with the concept of cognitive dissonance, where individuals experience psychological discomfort when their beliefs and behaviors are inconsistent [19,20]. In this case, the discrepancy between perceived and actual PA levels may have motivated these adolescents (i.e., the "Overestimators") to increase their activity to align with their self-perception [20]. Additionally, social norms within the summer program setting may have played a role [18]. As suggested by Priebe and Spink, descriptive norms about peers' PA levels can influence individual behavior [33]. The summer program environment may have provided exposure to more active peers, potentially encouraging Overestimators to increase their PA to conform to perceived group norms. Likewise, the "Underestimators" cluster, characterized by moderate levels of device-measured MVPA but low self-reported PA frequency, also demonstrated a significant increase in MVPA over the course of the summer program. This positive trajectory suggests that the summer care environment may have provided these adolescents with opportunities to engage in more PA than they typically perceive themselves capable of doing. The discrepancy between their actual and perceived PA levels could be attributed to low self-efficacy or a lack of awareness about what constitutes moderate to vigorous physical activity [21,23].

The decrease in MVPA observed in the "High Accuracy Actives" cluster is concerning and warrants further investigation. This decline could be attributed to several factors. One possibility is a ceiling effect, where individuals who start at high levels of activity have less room for improvement and may be more prone to regression towards the mean [34,35]. Another consideration is the potential for burnout or loss of motivation over time, especially if these highly active adolescents perceive their efforts as not being recognized or valued within the program context [36]. Additionally, the summer program structure may not have provided sufficient challenges or novel activities to maintain the interest and engagement of these already active participants [11]. These findings highlight the importance of tailoring program activities to support and encourage continued high levels of PA among initially active adolescents.

The identification of distinct clusters based on perceived and actual PA levels provides valuable insights for developing focused interventions within summer care programs. This approach aligns with calls for more personalized and nuanced strategies in PA promotion [37]. For "Underestimators", interventions could focus on building self-efficacy and providing positive feedback to help align their perceptions with their actual capabilities [38]. "Overestimators" might benefit from educational components about PA guidelines and self-monitoring techniques to increase awareness of their actual activity levels [39,40]. For "High Accuracy Actives", programs could implement strategies to prevent decline, such as offering leadership roles or introducing new, challenging activities to maintain engagement [41]. By tailoring interventions to these specific groups, summer care programs can more effectively address the unique needs and motivations of different adolescent subgroups.

Several limitations should be considered when interpreting the results of this study. First, the sample size was relatively small, which may limit the generalizability of the findings and the statistical power to detect smaller effects. Second, the study was conducted in a single summer care program in central Texas, and results may not be representative of adolescents in different geographic or socioeconomic contexts. Additionally, the self-reported PA measure, while validated, is subject to recall bias and social desirability effects. Finally, the study duration was limited to a single summer, and longer-term follow-up would be necessary to understand the stability of the identified clusters and their associated PA trajectories over time.

5. Conclusions

This study demonstrates the utility of cluster analysis in identifying distinct groups of adolescents based on their perceived and objectively measured PA levels within a summer care program context. The findings highlight the complex relationship between self-perceptions and actual behavior, as well as the differential responses of various subgroups to the program environment. The results suggest summer care programs can positively change adolescent PA, particularly for those who underestimate or overestimate their activity levels. However, strategies are needed to prevent declines among initial highly active participants. These insights can inform the development of more focused and effective PA promotion strategies within summer care programs, addressing the unique needs of different adolescent subgroups. Future research should focus on developing and testing tailored interventions based on these groups, as well as exploring the long-term stability and health outcomes associated with membership in these clusters.

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