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Original

TESTANDO LA HIPÓTESIS DE LA BARRERA DE COMPETENCIA MOTRIZ PARA LA ACTIVIDAD FÍSICA Y EL ESTADO PONDERAL EN JÓVENES

TESTING THE MOTOR PROFICIENCY BARRIER HYPOTHESIS FOR PHYSICAL ACTIVITY AND WEIGHT STATUS IN YOUTH

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RESUMEN

El objetivo fue determinar una barrera de competencia motriz (BC) para la actividad física (AF), el tiempo sedentario (TS) y el estado ponderal (EP) en dos etapas. En la Etapa 1, los valores de corte del cociente motor (QM), basados en la prueba KTK, para diferenciar el sobrepeso/obesidad del peso normal y el sedentario del no sedentario se identificaron en 734 participantes (353 niñas) de 10 años. En la Etapa 2, los valores de corte se usaron para definir grupos de QM bajo y alto (respectivamente por debajo y por encima de la BC) entre 217 jóvenes (118 niñas) de 12,9(0,4) años. El EP, la AF y el TS en los dos grupos de QM se compararon al inicio y 1,5 años después. Chi-cuadrado se usó para evaluar la independencia de la clasificación de QM bajo y alto en el EP, AF moderada-vigorosa (AFMV) y TS. Se calcularon los odds-ration de tener sobrepeso/obesidad y sedentarismo según el QM al inicio. Los QM de 79 para niñas y 75 para niños se definieron como la BC. En las niñas, la BC predijo clasificaciones significativamente diferentes del EP y una combinación de EP y AFMV. En los niños, la BC predijo clasificaciones significativamente diferentes en función del EP y AFMV combinados al inicio del estudio. Tener un QM por debajo de la BC se asoció con una probabilidad 2,78 mayor de tener sobrepeso/obesidad. En conclusión, los resultados sugieren que puede existir una BC que influye en la AF y el EP.

Palabras clave: habilidades motrices, niños, adolescentes, sobrepeso, competencia motriz, coordinación motriz, inactividad.

ABSTRACT

The purpose was to evaluate the implications of a proficiency barrier (PB) for physical activity (PA), sedentary time (ST) and weight status (WS) in a two-stage study. In Stage 1, motor quotient (MQ) cut-off values, based on the KTK test, for differentiating overweight/obese from normal weight, and sedentary from non-sedentary were identified in a sample of 734 children (353 girls) of 10 years of age. In Stage 2, the cut-off values were used to define low and high (respectively below and above the PB) MQ groups among 217 youth (118 girls) of 12.9(0.4) years of age. WS, PA and ST in the two MQ groups were compared at baseline and 1.5 years later. Chi-square tests were used to test the independence of low and high MQ classification on MS, moderate-to-vigorous PA, and sedentary time. Odds of being overweight/obese and sedentary according to MQ status at baseline were calculated. MQ of 79 for girls and 75 for boys were defined as the PB. In girls, the PB predicted significantly different classifications of WS, and a combination of WS and moderate-to-vigorous PA. In boys, the PB predicted significantly different classifications based on combined WS and moderate-to-vigorous PA at baseline. Having a MQ below the PB was associated with a 2.78 higher probability of being overweight/obese. In conclusion, the results suggest that a PB that influences PA and WS among youth may exist.

Keywords: movement skills, children, adolescents, overweight, motor competence, motor coordination, inactivity.

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INTRODUCTION

Promoting physical activity (PA), health-related physical fitness, and a healthy body weight among children and adolescents is a global concern and pursuit. Proficiency in a variety of movement skills, labeled motor competence (MC) (Robinson et al., 2015), is associated with habitual physical activity (PA) (Logan, Webster, Getchell, Pfeiffer, & Robinson, 2015; Lopes, Maia, Rodrigues, & Malina, 2011) and a healthy weight status during childhood (Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012; Lopes, Stodden, & Rodrigues, 2014; Robinson et al., 2015).

A trajectory leading to obesity associated with the cumulative effects of low MC, low PA and physical fitness (PF), and low self-perceptions of MC during childhood has been proposed (Stodden et al., 2008). Cross-sectional research has shown an inverse relationship between MC and the BMI (a proxy for body fatness) in both sexes across childhood into young adulthood, i.e., approximately 5-25 years (Castetbon & Andreyeva, 2012; Lopes, Stodden, et al., 2012), and a positive relationship between MC and PA during childhood and adolescence (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Limited longitudinal data also indicate MC as a predictor of PA (Lopes et al., 2011), PF (Barnett, Beurden, Morgan, Brooks, & Beard, 2008), body fatness (Lopes, Maia, Rodrigues, & Malina, 2012) and weight status (D'Hondt et al., 2013; Rodrigues, Stodden, & Lopes, 2016). It has also been hypothesized that low MC during childhood leads to decreased participation in play activities and/or sports during middle-late childhood and adolescence, resulting in a negative spiral of disengagement from a physically active lifestyle (Robinson et al., 2015).

MC during childhood is central to the mastery of more complex motor skills, including sports skills, at later ages (Branta, Haubenstricker, & Seefeldt, 1984). The observation that children with inadequately developed fundamental motor skills often had difficulty learning more complex skills lead to the proposal of a "proficiency barrier" (Seefeldt, 1980). Accordingly, specific levels of fundamental movement skills must be attained before more complex motor skills or tasks can be learned or mastered, and there may be a critical threshold of skill, labeled a "proficiency barrier" (PB), which individuals must surpass in order to successfully apply these skills in various activities including games and sports (Seefeldt, 1980). It has also been proposed that the lack of a solid foundation of fundamental movement skills may potentially impact lifelong PA, specifically activities that demand moderate-to-vigorous intensity (Branta et al., 1984). In the context of the preceding, movement skill levels below the threshold implied in the PB would contribute to a lack of success for children in activities that require a certain level of MC for participation and in turn would be potentially less successful in a variety of play activities, games and sports across childhood and would likely dropout at higher rates (Stodden, True, Langendorfer, & Gao, 2013). Moreover, habits of PA developed during childhood tend to track into adulthood (Telama et al., 2014).

The hypothesized PB may emerge during the transition from early into middle childhood, the interval during which fundamental movement patterns show "mature" characteristics and basic skills (running, jumping, hopping, throwing, etc.) are reasonably developed (Malina, 2014). Subsequently, movement skills are refined and integrated in a variety of activities experienced in free play, physical education and youth sports. It is thus possible that a PB may be more relevant later in childhood (~9-10 years) compared to the inferred transition based on fundamental movement patterns and basic motor skills.

The identification of a PB was attempted in a cross-sectional sample of adults 18-25 years of age (Stodden et al., 2013). An index of motor skill competence (MSC) was defined on the basis of maximum throwing and kicking velocity and distance jumped. Individuals with a very low probability (3%) of being physically fit (health-related fitness >60th percentile of the reference) demonstrated a low level of MSC (<35th percentile of the reference). On the other hand, only 1 of 65 individuals (1.5%) who had high MSC was classified as having "poor" health-related physical fitness. Overall, the results generally supported the concept of a PB associated with health-related physical fitness in young adults.

Potential associations between a PB associated with MC and levels of PA and physical inactivity and weight status have not been addressed. Many health-related behaviors, including PA, are established in childhood. If a PB in movement skills is related to multiple health-related variables in childhood, it may serve to inform policy addressing long-term negative trajectories in physical health (Stodden et al., 2008).

The purpose of this study was to determine if a PB in MC assessed by the Körperkoordinationstest für Kinder (KTK)/Body Coordination Test for Children (Kiphard & Schilling, 2007) was associated with PA, sedentary time (physical inactivity) and weight status in a longitudinal sample of youth. Taking in consideration the definition of MC, a person's proficiency to execute a broad range of motor skills and the underling mechanisms, such as motor coordination and control (Robinson et al., 2015; Utesch & Bardid, 2019), the use of KTK is adequate, moreover is a largely used test in Europe.

METHODS

Design

In order to test for the general idea of a PB hypothesis, we used a unique two-stage study design, with each stage using independent samples of children. The rationale for this procedure was that, if the PB exists and it is identified at the correct age (about 10 years of age), it can be tested at later ages. The notion of a PB existence entangles the developmental idea that future status (stages) can be dependent on the achievement of specific age-related behavioural patterns. The generalization of this hypothesis allow us to say that if the PB cut-off values are determined at the correct age (about 10 years of age), it can be used across individuals. This was our rationale for using a separate sample, with the correct age, to find a hypothesized PB value that was subsequently tested in a different longitudinal sample.

In stage 1, using a cross-sectional sample, we determined the most parsimonious model of a MC value (cut-off) that could distinguish overweight/obese from normal weight and sedentary from non-sedentary children at the age of 10 years using a Received Operations Characteristics (ROC) curve analysis.

In order to determine an MC cut-off value (PB), we tested its usefulness in another sample, and since the concept of PB would be best tested with longitudinal data (Stodden et al., 2013), in stage 2 we used a short term longitudinal data, with baseline and a 2-years late follow-up. At baseline (12 years of age), the postulated cut-off values of stage 1 were used to distinguish between children that were below or above the PB. These two groups' behavior was then investigated regarding their PA and weight status, at follow-up (14 years of age).

The ethics committee of the institution of the first author approved this research.

Stage 1

Participants

Data used for stage1 included a sample of 10 year old boys (n = 381) and girls (n = 353) associated with a previous study done in northeast region (Bragança) of Portugal. The procedures for data collection are described elsewhere (Lopes, Stodden, et al., 2012). All parents or guardians gave their informed consent, and children their assent, to participate in the study.

Anthropometric measures

Stature and body mass were measured using a stadiometer and a scale according to standardized procedures (Lohman, Roche, & Marttorell, 1988). Values were recorded to the nearest 0.1 cm and 100 g, respectively. Body mass index (BMI) was calculated [BMI=weight (kg)/height (m^2)]. Weight status was classified according to International Obesity Task Force (IOTF) cut-values for BMI (Cole, Bellizzi, Flegal, & Dietz, 2000; Cole, Flegal, Nicholls, & Jackson, 2007). Obese and overweight categories, and normal-weight and underweight categories both were collapsed leaving two weight status groups considered for the analysis; overweight and non-overweight children, respectively.

Motor competence

The Körperkoordinationstest für Kinder (KTK) (Body Coordination Test for Children) (Kiphard & Schilling, 2007), was used to evaluated children's MC. The KTK has excellent test–retest reliability with coefficients for individual tests ranging from 0.80 to 0.96 (Kiphard & Schilling, 2007). The KTK includes the assessment of the following items: (a) balance – child walks backward on three balance beams of 3 m in length that vary in width (6 cm, 4.5 cm, and 3 cm), starting with the widest and finishing with the narrowest; (b) jumping laterally - child makes consecutive jumps from side to side over a small beam (60 cm x 4 cm x 2 cm) as fast as possible for 15 sec; (c) hopping on one leg over an obstacle – the child is instructed to hop on one foot at a time over a stack of foam squares. After a successful hop with each foot, the height is increased by adding a square (50 cm x 20 cm x 5 cm); (d) shifting platforms – child begins by standing with both feet on one platform (25 cm x 25 cm x 2 cm supported on four legs 3.7 cm high); places the second platform alongside the first and steps on to it; the first platform is then placed alongside the second and the child steps on to it; the sequence continues for 20 seconds.

The raw performance score on each subtest was converted into a standardized "motor quotient" (MQ) adjusted for age and sex. The MQ was obtained after adding the standardized scores of each subtest (Kiphard & Schilling, 2007) and is a global indicator of gross motor coordination.

Physical activity

Physical activity was evaluated with the Godin and Shephard questionnaire (Godin & Shephard, 1985) which was administered in an interviewer-assisted format. Children were asked to report the number of time they spent more than 15 min in activities classified as mild (3 METs), moderate (5 METs), or strenuous (9 METs) in a typical week. A total score was derived by multiplying the frequency of each category by the MET value and summing the products (Godin & Shephard, 1985). Although the reported validity of this questionnaire with children is moderate, 0.32 to 0.42 (Scerpella, Tuladhar, & Kanaley, 2002), its relative simplicity facilitated its use with children in these large data sets.

Less-active and active children were identified according to their physical activity levels using the median as cut-off value.

Data analysis

To determine the MQ values that classify optimal cut-off values of overweight from non-overweight children as well as less-active from active children (i.e., PB models), we used Received Operations Characteristics (ROC) curve analysis, which determined the point of convergence of sensitivity and specificity (i.e., by simultaneously maximizing the two – the best trade off) separately for boys and girls.

Stage 2
Participants

Participants in stage 2 were part of the Longitudinal Analysis of Biomarkers and Environmental Determinants of Physical Activity (LabMed Physical Activity Study), a school-based prospective cohort study with Portuguese adolescents. The study design, sampling and procedures for this data collection are reported elsewhere (Agostinis-Sobrinho et al., 2016). Participants included in the present study were n = 217 (118 girls), aged 12.9(0.4) years at baseline. At baseline 90% of the girls and 75% of the boys were in Tanner 4 and 5 stages for sexual maturation.

All parents or guardians provided informed consent and children assented to participate in the study.

Anthropometric Measures

Stature and body mass were measured as described for stage 1. BMI was calculated [BMI=weight (kg)/height (m^2)] and weight status was classified using the same procedures as the stage 1. Additionally, BMI z-scores were computed based upon the WHO reference standards (WHO, 2006) to serve as a proxy measure of adiposity adjusted for age and gender.

Motor competence

Again, MC was evaluated with the Kiphard-Schilling body coordination test (KTK) (Kiphard & Schilling, 2007), already indicated and described in stage 1.

Physical activity and sedentary time

Physical activity and sedentary time were assessed with accelerometers GT1M (ActiGraph, Pensacola, Florida, USA). Participants were instructed to use the accelerometer attached on the right side of hip over five consecutive days (three weekdays, two weekend days) during waking hours and remove it during water-based activities. The epoch length was set to 2 seconds. Accelerometer data were analyzed by an automated data reduction program (Actilife 6.12, ActiGraph, Pensacola, Florida, USA). Periods with 60 minutes of consecutive zeros were detected and flagged as non-wear time. After screening, the raw activity "counts" were processed to determine time spent in the different physical activity intensities. Data were expressed as percentage of wear time. The cut-

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points proposed by Evenson, Catellier, Gill, Ondrak, and McMurray (2008) were used to determine physical activity intensities. Sedentary time was identified using a cut-point of <100 counts.min^{-1} (Trost, Loprinzi, Moore, & Pfeiffer, 2011). In our analysis we only considered data on sedentary time and moderate-to-vigorous physical activity (MVPA). Adolescents were categorized into two groups of physical activity and sedentary time according to the median values of these variables.

Data analysis

According to their MQ cut-off values found in study 1, the participants in stage 2 were split at baseline, in low MC and high MC by sex. Repeated measures ANOVA (2x2) were then performed to analyze the differences between participants with low and high MC at baseline, and the subsequent change in BMI z-score, sedentary time and MVPA.

A set of 2 X 2 Chi-square tests were conducted to test for the association of the hypothesized MC proficiency barrier groups with weight status, sedentary time, MVPA, and MVPA and weight status simultaneously. The Cramer' V was used as a measure of the effect size for chi-square test, and interpreted as small effect if V = 0.10, medium effect if V = 0.30, and large effect if V = 0.50 (Cohen, 1988).

Finally, we calculated odds rations (OR) adjusted for age and sex, trough logistic regression, of being overweight/obese, of having high sedentary time, of having low MVPA, and of simultaneous being overweight/obese and having low MVPA in second assessment, having low MC (below the proficiency barrier) in baseline.

RESULTS

Stage 1

Descriptive statistics (means and standard-deviations) for age, physical activity and MQs are summarized for boys and girls in Table 1, while results of the ROC analysis for the accuracy of classifications of boys and girls are summarized in Table 2. The MQ cut-offs that best discriminated between overweight and non-overweight and between less active and active children were selected as the threshold that maximized sensitivity and specificity. The best cut-off value for weight status was an MQ of 91 for boys and of 79 for girls. Corresponding values for physical activity were an MQ of 75 for boys and of 89 for girls.

Table 1: Descriptive Statistic (Mean and Standard Deviation) of Age, Body Mass Index (BMI), Physical Activity and Motor Quotient (MQ) for Boys and Girls of Study 1.

	Boys (n=381)	Girls (n=353)
Age (years)	10.4±0.4	10.4±0.4
BMI (kg/m2)	18.6±3.4	18.9±3.6
PA (#points)	55.0±41.4	43.4±37.4
MQ (#points)	86.9±15.0	75.9±14.0

Notes. BMI = body mass index; PA = physical activity; MQ = motor quotient

Table 2: Development of the Best Motor Quotient (MQ) Cut-off Values to Discriminate Overweight from Non-overweight, and Less Active from More Active Children, by Sex, According to the Best Trade-off Between Sensitivity and Specificity

		Best cut-off value		
	AUC	Cut-off	Sensitivity (%)	Specificity (%)
Boys				
Weight status	0.70	91	74.65	51.30
PA	0.60	75	84.50	27.94
Girls				
Weight status	0.70	79	70.71	58.73
PA	0.59	89	19.64	88.39

Notes. PA = physical activity; AUC = area under the curve

The lower values for the MQ in each sex, 75 in boys and 79 in girls, were retained as the indicator of the PB for further analysis in stage 2, since a lower MQ is more conservative. There is a higher likelihood of obtaining a meaningful separation of overweight from non-overweight and of less active from active participants with a lower value for the MQ.

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Stage 2

Descriptive statistics for age, the BMI, MQ, MVPA and sedentary time for boys and girls at baseline and at follow-up are summarized in Table 3.

Table 3: Descriptive Statistic (Mean and Standard Deviation) of Age, Body Mass Index (BMI), Physical Activity and Motor Quotient (MQ) in Baseline and in Follow-up for Boys and Girls of Study 2.

	Baseline		Follow-up	
	Boys (n=99)	Girls n=118)	Boys (n=99)	Girls (n=118)
Age (years)	12.9(0.4)	12.8(0.4)	14.6(0.3)	14.6(0.3)
BMI (kg/m2)	19.8(3.1)	20.9(3.8)	20.6(2.9)	22.3(3-5)
MQ (#points)	94.75(14).0	84.3(15.2)	107.8(13.4)	89.2(16.3)
MVPA (min/day)	65.4(23.5)	43.9(13.8)	59.3(21.4)	46.8(17.7)
Sed (min/day)	552.7(61.4)	552.6(55.4)	532.2(70.8)	525.2(64.2)

Notes. BMI = body mass index; PA = physical activity; MQ = motor quotient; Sed = sedentary time; MVPA = moderate-to-vigorous physical activity

Table 4: Chi-square Cross-tabulation for Motor Quotient (MQ) Cut-off X Weight Status; sedentary Time, Moderate-to-vigorous Physical Activity (MVPA), and Combined Weight Status and MVPA in Both Time-point Assessments for Girls.

		T1				T2			
		MQ				MQ			
		Below PB	Above PB	χ2	V	Below PB	Above PB	χ2	V
Weight status	Overweight	32	10	5.32 *	0.21 *	24	17	11.78 ***	0.32 ***
	Normal weight	41	34			20	56		
Sedentary time	Low	28	15	0.78	0.10	9	16	0.04	0.03
	High	24	19			10	16		
MVPA	Low	27	17	0.03	0.02	17	31	0.02	0.01
	High	25	17			13	25		
Weight status and MVPA	Obese and Sedentary	27	0	44.0 ***	1 ***	11	6	5.23 *	0.35 *
	Active and normal weight	0	17			8	19		

*Notes. T1 = baseline; T2 = follow-up; MQ = motor quotient; PB = proficiency barrier; MVPA = moderate-to-vigorous physical activity; χ2 = Chi-square; V = Cramer's V; * = significant for p < 0.05; ** = significant for p < 0.01; *** = significant for p < 0.001*

Results of the repeated measures ANOVA of BMI z-scores indicate a non-significant effect of Time ($F_{(1, 215)} = 3.67$; $p = 0.057$) and a non- significant interaction between Time and MQ status (below and above the PB) at baseline ($F_{(1, 215)} = 0.56$; $p = 0.456$). The repeated measures ANOVA for sedentary time show a significant Time effect ($F_{(1, 215)} = 4274.9$; $p < 0.001$), i.e., a significant increase in sedentary time, and a non-significant interaction between Time and MQ status ($F_{(1, 215)} = 0.74$; $p = 0.393$). And, the repeated measures ANOVA for MVPA show a significant Time effect ($F_{(1, 215)} = 3.99$; $p < 0.049$), i.e., a significant decrease in MVPA, and non-significant interaction between Time and MQ status ($F_{(1, 215)} = 0.02$; $p = 0.881$). Overall, the results indicate that the possible association between MQ groups and the three dependent variables (BMI, sedentary time, MVPA) are rather stable over time.

Results of the Chi square analyses of the cross-tabulations of MQ status (low and high) with, respectively, weight status (overweight vs non-overweight), sedentary time (high vs low), MVPA (high vs low), and combined weight status and MVPA (overweight and low MVPA vs non-overweight and high MVPA) at both time points are summarized in Table 4 for girls and in Table 5 for boys. MQ status (low versus high) predicts significantly different classifications of weight status ($\chi^2_{(1, n = 117)} = 5.32$, $p < 0.05$, V = 0.21), and combined weight status and MVPA ($\chi^2_{(1, n = 44)} = 44.0$, $p < 0.001$, V = 1) at baseline, and of weight status ($\chi^2_{(1, n = 117)} = 11.78$, $p < 0.001$, V = 0.32) combined weight status and MVPA ($\chi^2_{(1, n = 44)} = 5.23$, $p < 0.05$, V = 0.35) at follow-up in girls (Table

4). MQ status is effective in differentiating the combined weight and MVPA status for boys only at baseline ($\chi^2_{(1, n = 37)} = 37.0$, $p < 0.001$, V = 1); the other cross-tabulations are not significant in boys (Table 5).

Odds ratios, based on logistic regression adjusted for age and sex, for weight status, sedentary time, MVPA, and weight status and MVPA combined at follow-up relative to baseline MQ status classification based on the PB cut-off are summarized in Table 6. The probability of being overweight at follow-up for individuals below the PB (low MQ) at baseline is 2.78 times greater than for individuals above the PB (high MQ) at baseline. For youth both overweight and having low MVPA at baseline, the OR is 2.52, but not significant. The ORs for sedentary time and MVPA are low and not significant.

Table 6: Odds-ratio (OR) Adjusted for Age and Sex, of being Overweight/Obese, Have High Sedentary Time, Have Low Moderate-to-vigorous Physical Activity (MVPA), and Simultaneous Being Overweight/Obese of Having Low Motor Quotient.

Dependent variable	OR	p value	IC95%
Weight status	2.78	0.008	2.01 – 3.54
Sedentary time	1.23	0.68	0.47 – 3.24
MVPA	0.89	0.76	0.40 – 1.97
Weight status and MVPA	2.52	0.19	0.63– 10.16

Notes. MVPA = Moderate-to-vigorous physical activity

Table 5: Chi-square Cross-tabulation for Motor Quotient (MQ) Cut-off X Weight Status; sedentary Time, Moderate-to-vigorous Physical Activity (MVPA), and Combined Weight Status and MVPA in Both Time-point Assessments for Boys.

		T1				T2			
		MQ				MQ			
		Below PB	Above PB	$\chi2$	V	Below PB	Above PB	$\chi2$	V
Weight status	Overweight	3	18	1.38	0.12	2	12	0.85	0.10
	Normal weight	5	73			6	79		
Sedentary time	Low	2	35	0.16	0.05	3	21	0.27	0.07
	High	3	36			2	23		
MVPA	Low	2	36	0.21	0.05	2	35	0.16	0.05
	High	3	35			3	36		
Weight status and MVPA	Obese and Sedentary	2	0	37.0 ***	1 ***	0	4	0.13	0.06
	Active and normal weight	0	35			1	32		

*Notes. T1 = baseline; T2 = follow-up; MQ = motor quotient; PB = proficiency barrier; MVPA = moderate-to-vigorous physical activity; $\chi2$ = Chi-square; V = Cramer's V; * = significant for p < 0.05; ** = significant for p < 0.01; *** = significant for p < 0.001*

DISCUSSION

The influence of the postulated proficiency barrier (PB) to the development of motor skills (Seefeldt, 1980) on weight status, physical activity and sedentary time was evaluated in a two-stage design. The first stage defined levels of motor coordination (KTK battery, (Kiphard & Schilling, 2007) defined by the MQ which discriminated overweight from non-overweight and less active from active children. It was assumed that children have accumulated sufficient experiences in the development of movement proficiency by 10 years of age in contrast to younger ages, which are characterized by considerable inter-

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and intra-individual differences in the attainment of mature movement patterns and basic skills (Malina, Bouchard, & Bar-Or, 2004; Seefeldt & Haubenstricker, 1982). Given the range of individual differences at younger ages, cut-off values for an indicator of a PB at 10 years of age may be useful to evaluate outcomes associated lower levels of movement proficiency at later ages, e.g., weight status, PA and physical inactivity.

Application of the PB, defined by low and high MQs based on the KTK test of motor coordination, to the short-term longitudinal sample indicated no changes from baseline to follow-up in BMI z-scores, sedentary time and MVPA for youth below and above the proposed PB. Chi-square results indicated that a PB based on the KTK MQ may be evident for a healthy body weight and MVPA, but not for sedentary time. The MQ cut-offs also discriminated between youth who were overweight and had low MVPA from youth who were normal weight and had adequate MVPA. Moreover, the robustness of the Chi-square results suggested that if youth do not achieve a KTK MQ of at least 75 in boys and 79 in girls during early and mid-adolescence, the risk of being less active and overweight was increased.

The results for sedentary time likely reflected, in part, the fact that sedentary time is a different entity than PA (Biddle et al., 2009), and that many forms of sedentary time (school, study, television viewing, etc.) are highly valued by society. Moreover, active children are not necessarily those with less sedentary time (Tremblay et al., 2011).

The MQ cut-offs used to identify a potential PB in the present study were within the interval of values proposed by the developers of the KTK test (Kiphard & Schilling, 1974, 2007) to classify children having a 'moderate motor disorder'. These values may also be used to identify children who may be in need of special attention to improve their motor proficiency with the objective of promoting a more active lifestyle and maintaining healthy weight status.

The present study was apparently the second to evaluate the postulated PB in motor proficiency (Seefeldt, 1980), and was the first to evaluate the postulate in children and adolescents. Although the results of the short term longitudinal observations among youth were not as strong as observations regarding a PB and health-related PF in a cross-sectional sample of young adults (Stodden, Langendorfer, & Roberton, 2009), the longitudinal observations did yield significant results. A longer follow-up interval spanning adolescence may provide a better understanding of how the PB in motor proficiency may play out across time.

It is plausible, nevertheless, to assume that children and youth who do not develop a suitable level of movement proficiency may be less prepared to perform more complex motor tasks inherent to a variety of unstructured and structured games and sports. Such experiences associated with deficiency in motor proficiency may, in turn, lead to a decreased level of habitual PA and unhealthy weight gain across adolescence and into adulthood. On the other hand, children and youth more proficient in a variety of movement skills may engage in physical activities which foster the further development of motor proficiency which in turn may contribute to higher levels of PA and a greater likelihood of maintaining a healthy weight status (Stodden et al., 2008).

Positive and/or negative trajectories in PA and weight status associated with motor proficiency have been previously demonstrated in longitudinal studies (D'Hondt et al., 2014; Lopes et al., 2011). Boys and girls in the highest tertile of motor coordination (KTK) did not decline in PA between 6 and 10 years, while those in the middle and lowest tertiles of motor coordination decline in PA over this interval (Lopes et al., 2011). The KTK MQ cut-offs for the lowest tertile in this study (74 in boys and 85 in girls) (Lopes et al., 2011) were similar to those identified in the present analysis. On the other hand, children with lower performance on the KTK at baseline predicted an increase in the BMI z-score two years later (D'Hondt et al., 2014). In a related cross-sectional analysis, less than 20% of healthy-weight children were identified as "motor impaired" (MQ <85 or 15th percentile), while proportions of overweight and obese children classified as "motor impaired" increased, respectively to 43% and 71% (D'Hondt et al., 2011). Though limited, the data suggested a potential PB defined by motor coordination that was associated with PA and weight status over an interval of two years. By inference, appropriate instruction, guidance and opportunity for practice of motor skills during

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childhood and youth may facilitate the development of a physically active lifestyle.

Although the present study included a short-term longitudinal perspective, longer-term studies are needed to provide further insight into the hypothesis of a PB for motor skill as a factor influencing PA and weight status. PA was measured by a questionnaire in stage 1 and with accelerometry in stage 2 which is a potential limitation. The PB used in the study was defined by the four tests of the KTK test of motor coordination, which is also a potential limitation. There is a need to consider other indicators of motor skill in the development of cut-offs for a potential PB.

The demands and expectations of different cultures influence the social contexts in which children are reared. These contexts include, for example, home, play, school, sport, and others, which may influence the emphasis and value placed upon and the development of proficiency in movement tasks. The influence of variation in social contexts and expectations on the development of movement proficiency, however, has not received much attention. The present paper was set within a European setting, and addressed potential implications of the hypothesized PB (Seefeldt, 1980) defined by motor coordination on PA, inactivity and weight status in adolescence. The observations need to be extended to other indicators movement proficiency and also to other cultural settings.

CONCLUSIONS

The purpose of this study was to determine if a PB in MC assessed by KTK was associated with PA, sedentary time and weight status in a longitudinal sample of youth.

KTK motor quotients of 75 and 79 for boys and girls, respectively, were evaluated as potential proficiency barriers in motor proficiency to differentiate overweight and non-overweight and active and less active youth. The cut-off for girls was reasonably successful in differentiating youth by weight status and PA, while that for boys was not as successful. Independent of sex, however, the probability of being overweight two years after baseline among youth with motor proficiency below the hypothesized PB was significantly higher than among youth with motor proficiency above the PB. Overall, results of the present study suggest that a proficiency barrier in motor proficiency may exist, specifically in the context of maintaining a healthy weight status and a physical active lifestyle PA.

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