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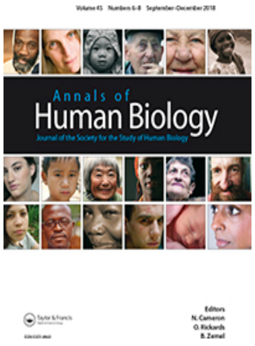

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RESEARCH PAPER

Familial resemblance in gross motor coordination. The Peruvian Sibling Study on Growth and Health

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ABSTRACT
Background: The development of gross motor coordination (GMC) is governed by biological and environmental factors whose effect sizes are still unclear.
Aim: To investigate sibling resemblance in GMC, as well as biological and environmental correlates of GMC among Peruvian children.
Materials and methods: The sample comprised 1256 biological siblings (6–15 years old), from three geographical areas of Peru. GMC was assessed using the *Korperkoordinationtest für Kinder* (KTK) test battery. Anthropometry, biological maturation and physical fitness (PF) were also measured. Multilevel modelling was performed using Stata 14 software.
Results: In general, sister–sister pairs (SS) showed the highest resemblance in GMC ($\rho = 0.24$) compared to brother–sister (BS) ($\rho = 0.10$) and brother–brother (BB) pairs ($\rho = 0.07$). On average, BB pairs had higher GMC than SS pairs and older siblings had higher GMC than younger siblings. Further, those with lower body mass index (BMI) and higher PF had higher GMC. There was also a significant interaction between age and PF with GMC. Siblings from the rainforest region demonstrated higher GMC than those from sea level and high-altitude siblings demonstrated lower GMC than their sea-level peers.
Conclusion: These results demonstrate statistically significant sibling resemblance in GMC. Age, BMI, PF and geographical area were significant correlates of GMC.

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Familial aggregation; gross motor coordination; youth; siblings; Peru

Introduction

The development of gross motor coordination (GMC) results from complex and additive interactions among neurological, neuro-motor, experiential and environmental constraints (Keogh and Sugden 1985; Newell 1986). Adequate levels of GMC are achieved with sufficient practice and experiences with a variety of different movement forms under a variety of environmental contexts and are associated with healthy traits in children and adolescents (Robinson et al. 2015; Barnett et al. 2016).

An increase in GMC is generally expected with increasing age (Chaves et al. 2015; Henrique et al. 2018), although this is not always the case (Rodrigues et al. 2016) as biology, experience and environmental influences reciprocally interact to promote positive or negative developmental trajectories of GMC across childhood and adolescence (Stodden et al. 2008; Barnett et al. 2016; Rodrigues et al. 2016). Factors such as physical fitness (Stodden et al. 2014; Cattuzzo et al. 2016) and body fatness (Lopes et al. 2012; D'Hondt et al. 2013) also confound this association across age (Chaves et al. 2015). Biological maturation affects GMC development, mainly due to differences among individuals in the timing and tempo of the pubertal growth spurt (Malina et al. 2004; Freitas et al. 2016). Sex-specific differences in GMC have also been reported, mostly favouring boys (Barnett et al. 2016; Freitas et al. 2016).

However, GMC shows heterogeneity at the population level, which is the result of genetic, experiential and environmental factors and their interactions (Kovář 1981; Clark and Metcalfe 2002). In Peru, given the clear delimitation of geographical areas (high altitude, sea level and rainforest), an altitude-based effect on children's and adolescents' physical activity and physical fitness characteristics is expected. For example, a previous study with Peruvian children showed that those living in the rainforest areas were stronger and more flexible than those living at sea level or high altitude;

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further, those living at high altitude had higher cardiorespiratory fitness (Bustamante Valdivia et al. 2015). These results may reflect differences in types and patterns of daily chores and subsistence activities, as well as lifestyle behaviours. Furthermore, different opportunities and times to play, available spaces and types of games, as well as equipment and material may also differ across physical environments and affect development of motor coordination (Newell 1986; Chaves et al. 2016). Because environmental factors play a fundamental role in shaping children's and adolescents' lives, locational issues are of chief importance for addressing motor development and health matters. A variety of place-based influences, including natural circumstances (e.g. altitude, temperature regimes and pollutants), social context (e.g. social networks, access to care, perception of risk behaviours) and economic conditions (e.g. quality of nutrition, access to health insurance) are of importance.

Family data, including siblings and twins, have been used to investigate the influence of shared (genetic and environmental) and non-shared factors on a variety of traits (Plomin et al. 2013), and shared factors play an important role in familial resemblance (Maia et al. 2014; Pereira et al. 2017). Further, using samples of related individuals (siblings and/or twins) provides a unique way to investigate why individuals within the same family are similar or dissimilar in GMC. However, available data regarding GMC similarity among relatives are scarce; we were only able to identify two reports. Chaves et al. (2012), using Portuguese twins and the *Korperkoordinationstest für Kinder* (KTK) test battery, showed higher resemblance in monozygotic ($\rho = 0.88$) than in dizygotic ($\rho = 0.68$) twins. Additionally, environmental factors were apparently more important than genetic factors in explaining the total variance in twins' GMC performance. Likewise, Wrotniak et al. (2009) assessed 23 sibling pairs with the Bruininks-Ozeretsky test battery and found significant sibling similarities for walking on a balance beam, manual dexterity and fine motor integration. Although relevant, these studies did not consider the effects of any putative covariates on GMC.

Although siblings share, on average, 50% of their genes identical-by-descent (Falconer and Mackay 1996) as well as common familial environments, they can differ in age, sex, physical growth and biological maturation, for example, and these factors may help to explain subjects' heterogeneity in GMC levels. Therefore, based on the multilevel model (subjects nested within sib-ships), the aim of the present study was twofold: (1) to investigate the associations of biological and environmental characteristics with GMC among Peruvian child and adolescent siblings living in three different geographical areas; and (2) to estimate the level of sibling resemblance in GMC.

Subjects and methods

Study participants

The sample came from the Peruvian Sibling Study on Growth and Health, which investigated physical growth, different markers of motor development and health aspects of children and adolescents living in three different geographical areas: sea-level, rainforest and high altitude (Bustamante et al. 2011). A sample of 1256 biological siblings, 560 boys and 696 girls, aged 6–15 years with a wide range of age differences, was obtained from public schools in three natural regions of central Peru: sea level, located between the western mountain and the Pacific Ocean (Barranco, 58 m of altitude); high altitude, located in the central part of the Andes Mountains (Junín, 4107 m of altitude); and rainforest, the largest Peruvian territory (La Merced and San Ramon, 751 m of altitude). All data were collected between March 2009 and July 2011, during the same time periods to avoid seasonal effects. Within each school, all children were invited to participate. The response rate was 98%.

Formal permission was obtained from school authorities and written informed consent and assent were obtained from the children, parents or legal guardians. The project was approved by the National University of Educación Enrique Guzmán y Valle (UNE EGyV) ethical committee (Resolution: 2459-R-2008-UNE).

Gross motor coordination

Gross motor coordination was assessed with the KTK test battery (Kiphard and Schilling 1974), which includes the following tests: (1) walking backwards along a balance beam; (2) jumping sideways over a slat; (3) hopping for height on one foot; and (4) moving sideways on boxes. The raw scores of each test were summed to express the overall GMC score (mSchilling 2015).

Anthropometry

Height and sitting height were measured to the nearest 0.1 cm with a portable stadiometer (Sanny, Model ES-2060, Brazil). Body mass was measured to the nearest 0.1 kg using a digital scale (Pesacon, Model IP68, Peru). Body mass index (BMI) was obtained by the ratio of body mass to height (kg/m^2). All measurements were made according to standardised procedures (Lohman et al. 1988).

Biological maturation

Maturity offset uses sex-specific equations with age, body mass, height, sitting height and leg length to predict the distance each participant is from her/his expected age of the attainment of peak height velocity (PHV) (Mirwald et al. 2002). A positive maturity offset represents the number of years the participant is beyond PHV, whereas a negative maturity offset represents the number of years the participant is before PHV.

Physical fitness

Physical fitness was assessed with four tests from the EUROFIT battery (Committee of Experts on Sports Research 1993): handgrip strength, standing long jump, shuttle-run and sit-and-reach. The curl-up was an additional measure of physical fitness and was performed in accordance with Fitnessgram® protocols (Welk and Meredith 2008). A 12 minute run was also administered (AAHPERD 1980). Z-scores were derived from each fitness test to transform all test scores to the same metric; then, the sum of these scores was used as an indicator of total PF as advocated (Huang and Malina 2007; Lu et al. 2014; Stodden et al. 2014)

Data quality control

Data quality control was assured using two approaches. First, a systematic training of team members was conducted, which consisted of studying and learning all methodological procedures set by the lead researchers of the project. This was followed by a pilot study that was conducted at the UNE EGyV. Second, a reliability-in-field procedure was used where three to five students were randomly selected on alternating assessment days and re-tested. Technical errors of measurement (TEM) for height, body mass and sitting height were 0.2 cm, 0.1 kg and 0.1 cm, respectively. Test–re-test reliabilities for motor tests ranged from 0.87 (12 minute run) to 0.98 (standing long jump) for PF, and between 0.78 (hopping for height on one foot) and 0.92 (moving sideways on boxes) for GMC.

Statistical analysis

Exploratory data analysis was conducted to detect missing values and the presence of outliers. Descriptive statistics and ANOVA [test for mean differences between brother–brother (BB), sister–sister (SS) and brother–sister (BS)] were computed using SPSS 23 (IBM SPSS Corporation, New York, NY). Since individuals were nested within sib-ships, i.e. data were clustered, we used a multilevel model as implemented in STATA 14. In total, 88 families had three siblings ($n = 264$ subjects), 19 families had four siblings ($n = 76$ subjects) and three families had five siblings ($n = 15$ subjects). However, in the present study we only analysed families with two siblings ($n = 1256$ subjects).

Multilevel modelling was conducted in a sequence of steps. The null model (M_0), with no covariates, provided a partitioning of the variance between level 1 and level 2 and served as the benchmark to be compared to other models of increasing complexity (Hox 2010); the next model (M_1) included biological covariates, namely age, age^2, BMI, maturity offset and the PF z-score sum; the final model (M_2) added geographical location (dummy variable with coast as reference). All covariates were centred at their respective means as advocated (Hox 2010). Based on a statistical approach developed by Hedeker et al. (2012), which expands the classical multilevel model, we estimated separate within- and between-siblings variances, and therefore separate intraclass correlations (ρ); 95% confidence intervals (95% CI) for the three sibling types [brother–brother (BB), sister–sister (SS) and brother–sister (BS)] were also computed. Unadjusted, partially adjusted (age, age^2, BMI, maturity offset and PF z-scores) and fully adjusted (including geographical location) intraclass correlations were computed. In all models, the brother–brother (BB) pairs was the reference category. All parameters were simultaneously estimated using maximum likelihood (Goldstein 2003).

Results

Descriptive characteristics for anthropometry, maturity offset, GMC and PF are presented in Table 1. Sibling pairs had similar anthropometric characteristics; however, SS pairs were more mature than BB and BS pairs. With respect to GMC, BB and BS pairs outperformed SS pairs in hopping for height and moving sideways tests, while BS pairs were better

Table 1. Descriptive statistics (mean and standard deviations), F-tests and post-hoc comparisons by type of sib-ship.

	Brother–Brother ($n = 286$)		Sister–Sister ($n = 424$)		Brother–Sister ($n = 546$)			
	Mean	SD	Mean	SD	Mean	SD	F	Post-hoc comparisons
Age (years)	10.8	2.7	10.8	2.7	11.0	2.7	1.5^{ns}	
Age difference (years)	2.4	2.5	2.6	2.4	2.8	2.3	2.7^{ns}	
Anthropometry								
Height (cm)	135.0	15.6	135.3	15.0	135.2	15.0	0.1^{ns}	
Weight (kg)	35.3	12.9	35.0	12.0	34.3	11.0	0.8^{ns}	
BMI (kg/m^2)	18.7	3.5	18.5	3.3	18.3	2.8	2.4^{ns}	
Maturity offset (years)	−2.5	2.3	−2.0	2.1	−2.1	2.2	4.9*	SS > BB
Gross motor coordination (points)								
Walking backwards	49.7	13.5	49.3	13.7	52.4	12.6	7.8**	BS > BB and SS
Jumping sideways	49.8	13.6	49.8	14.6	50.7	13.8	0.6^{ns}	
Hoping for height	51.7	19.4	46.4	17.3	50.6	17.7	9.1**	BB and BS > SS
Moving sideways	21.2	5.2	20.0	4.5	21.0	5.0	7.5**	BB and BS > SS
GMC score (sum of points)	176.4	41.2	165.8	39.4	174.7	39.8	6.5*	BS > SS
Physical fitness								
12 minute run (m)	1541.2	404.2	1328.8	310.0	1480.7	426.6	28.9**	BB and BS > SS
Handgrip strength (kg)	15.6	7.8	13.4	5.6	14.8	6.8	9.5**	BB and BS > SS
Standing long-jump (cm)	122.3	25.9	113.1	24.1	119.1	25.0	13.2**	BB and BS > SS
Curl-ups (rep)	40.8	19.0	33.9	17.2	38.4	18.9	13.5**	BB and BS > SS
Shuttle-run (s)	23.6	3.9	25.3	3.1	24.9	3.5	21.1**	BB > SS and BS
Sit and reach (cm)	22.6	5.4	23.0	5.6	22.2	5.4	2.3^{ns}	
Total physical fitness (sum of z-scores)	−0.1	3.1	−1.0	2.3	−0.3	2.8	10.5**	BB and BS > SS

ns: non-significant.
*$p < 0.01$; **$p < 0.001$.

Table 2. Parameter estimates, standard errors (SE), variance components and intraclass correlation of the three nested models.

	Null Model (M_0)		Model 1 (M_1)		Model 2 (M_2)	
Fixed effects	Estimate	SE	Estimate	SE	Estimate	SE
Intercept (BB)	172.36	2.55	183.10	4.28	188.16	4.36
SS	−6.92	3.31*	−4.10	2.39^{ns}	−6.16	2.25**
BS	2.33	3.10^{ns}	0.98	1.87^{ns}	0.68	1.79^{ns}
Age			9.78	1.18***	9.14	1.14***
Age^2			−1.65	0.13***	−1.57	0.13***
Maturity offset			−0.71	1.57 ^{ns}	0.97	1.53^{ns}
BMI			−1.24	0.30***	−1.86	0.30***
PF			3.16	0.51***	3.20	0.51***
Interaction Age-by-PF			0.33	0.12**	0.30	0.12**
Interaction SS-by-PF			−0.60	0.73 ^{ns}	−0.33	0.71^{ns}
Interaction BS-by-PF			0.52	0.59 ^{ns}	0.72	0.57^{ns}
High altitude					−11.39	2.32***
Rainforest					6.90	2.15**
Variance components (σ^2)						
Between siblings (σ^2_B)						
BB	132.85	147.12	44.84	45.39	34.73	42.26
SS	310.23	113.79	243.12	55.14	148.85	47.98
BS	83.72	96.88	117.46	38.31	47.84	33.20
Within siblings (σ^2_w)						
BB	1555.00	188.88	443.26	56.25	430.12	53.71
SS	1241.75	124.85	464.35	48.91	467.29	49.44
BS	1494.72	129.61	452.64	41.90	454.56	41.92
Intraclass correlation (ρ)		95% CI		95%CI		95%CI
BB	0.08	0.01–0.47	0.09	0.01–0.47	0.07	0.01–0.51
SS	0.20	0.10–0.37	0.34	0.23–0.48	0.24	0.13–0.41
BS	0.05	0.01–0.38	0.21	0.11–0.36	0.10	0.02–0.32

BB: brother–brother; SS: sister–sister; BS: brother–sister; BMI: body mass index; PF: physical fitness; ns: non-significant.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

performers than BB and SS pairs in walking backwards. The different sibling pairs had similar performances in jumping sideways. BS pairs showed higher GMC scores than SS pairs but were similar to BB pairs. For PF, BB and BS pairs were stronger (handgrip, standing long jump and curl ups) and performed better than SS pairs in the 12 minute run; BB pairs also outperformed SS pairs in the shuttle-run. For the sit-and-reach test, scores were similar among the different types of sibling pairs.

Results from the multilevel analysis are shown in Table 2. In the null model, BB GMC score was, on average, 172.36 and did not differ from BS pairs (172.36 vs 174.69, $p > 0.05$); on average, SS pairs had lower GMC than BB pairs (172.36 vs 165.44, $p < 0.05$). In Model 1, the BB average GMC score was 183.10 (when all other covariates equal zero) and was not significantly different from SS and BS pairs. Older children had higher GMC ($\beta = 9.78 \pm 1.18$, $p < 0.001$) than younger peers. BMI was negatively associated with GMC ($\beta = -1.24 \pm 0.30$, $p < 0.001$) and those with higher levels of PF had higher GMC ($\beta = 3.16 \pm 0.51$, $p < 0.001$) than children with lower PF. Maturity offset was not statistically associated with GMC ($p > 0.05$). There was a significant age-by-PF interaction ($\beta = 0.33 \pm 0.12$, $p < 0.01$) with GMC, i.e. a combined effect of age and PF was associated with high GMC; however, PF did not significantly interact with sibling types to affect their GMC. In Model 2, the addition of geographical location showed that children and adolescents living at high altitude had lower GMC than those living at sea level ($\beta = -11.39 \pm 2.32$, $p < 0.001$), but those living in the rainforest had higher GMC ($\beta = 6.90 \pm 2.15$, $p < 0.01$) than their peers living at sea level. In all models and based on intraclass correlations there was evidence of sibling similarity in GMC. SS pairs were most similar, followed by BS and BB pairs. The inclusion of biological covariates increased sibling similarity, but, when the physical environment was added, the strengths of correlations decreased (see Table 2).

Discussion

Available research on sibling similarity in GMC mostly comes from twin studies, although such data are scant. Given the twin study design and related assumptions (Plomin et al. 2013), monozygotic (MZ) pairs' intraclass correlations are usually higher than those from dizygotic (DZ) pairs, and these correlations are also always higher than those found in non-twin sibs, whatever the phenotype under scrutiny (Bouchard et al. 1997). Using GMC data, Chaves et al. (2012) reported that MZ twin pair correlations were higher ($0.73 \leq \rho \leq 0.89$) than DZ pair correlations ($0.61 \leq \rho \leq 0.69$). Similarly, Lopes et al. (2014), using the Zurich Neuromotor test battery, found correlations of $0.42 \leq \rho \leq 0.75$ for MZ twins and of $0.41 \leq \rho \leq 0.56$ for DZ twins. These results suggest the importance of genetic factors in the expression of GMC levels. However, in these studies twin pairs were classified as MZ or DZ and no sex classes were analysed, which limits the comparisons with our data. However, they parallel the range reported by other researchers for other motor competence phenotypes (Bouchard et al. 1997).

The pattern of intraclass correlations found in our study suggests that SS pairs have greater resemblance in GMC than BS and BB pairs. This result differs from other reports with non-twin siblings for some physical fitness tests, in which BB pairs showed higher similarity (Saranga et al. 2010; Pereira et al. 2017), but is similar to the pattern observed in physical activity resemblance (Pereira et al. 2018). One possible explanation for the observed differences is related to the dynamics of the traditional structure of Peruvian families. In general, daughters have more restrictions relative to their involvement in sports and recreational activities inside and outside of the house. Inside the home they share the same recreational activities and domestic chores. Likewise, when they have the opportunity of attending any institution for sports activities, the younger sisters tend to participate in the same sport as the older sister. Male children have more opportunities to diversify their recreational and sports activities inside and outside the home.

Notwithstanding the fact that the SS pairs are higher in similarity in GMC, they also had, on average, a poorer performance compared to BB pairs. Sex differences in GMC are well known, showing that boys usually outperform girls (Malina et al. 2004; Barnett et al. 2016). For example, in a longitudinal study of Portuguese children, Antunes et al. (2016) showed that boys tend to perform better than girls on all GMC tests. Similarly, Chaves et al. (2016) showed that girls are approximately five times more likely to have lower GMC levels than boys. These differences may be linked to sociocultural influences, i.e. girls may be less encouraged to practice physical and/or sports-related activities, which, in turn, may provide less opportunities to develop their GMC (Malina et al. 2004). In addition to differences promoted in sociocultural contexts, boys benefit from overall body size advantages and higher levels of strength, which can significantly influence the development and performance of GMC (Barnett et al. 2016).

As children become older, taller, heavier and stronger and with more life experience, it is expected that their GMC will increase, as previously reported in German (Ahnert et al. 2009), Belgian (Vandorpe et al. 2011) and Portuguese children (Henrique et al. 2018). However, Chaves et al. (2016) also showed that, with increasing age, a significant increase in the probability of demonstrating low GMC was found. Overall, increases in GMC with age do not exclusively correspond to the prevalence of age-specific disability, but it is possible that, during the pubertal growth spurt, performance could be impaired by the non-synchronicity in the growth of different body parts. Using a unique person-centred approach, Rodrigues et al. (2016) also demonstrated a significant proportion of children showing little or no change in raw scores of motor and fitness performance across 3 years. In a different vein, biological maturation has been consistently noted as an important confounding factor in motor performance of children and adolescents. However, recent findings have demonstrated biological maturation has mostly shown small (Freitas et al. 2016; Luz et al. 2016) or no influence on GMC (Vandendriessche et al. 2012), despite being an important factor to identify low levels of motor coordination (Chaves et al. 2016). From a dynamical systems perspective, the continuous reorganisation (i.e. coordination) of changing degrees of freedom (i.e. growth) of the human system (i.e. anthropometrics/limbs) and parameterisation of this function (control) occurs in real time across childhood and adolescence (Newell 1986). However, the absence of developmentally appropriate experiences and interactions with the environment, as well as other individuals, may severely impair the development of GMC, motor performance and physical fitness. Over time, these impairments may compound and reciprocally influence each other, fostering decreased habitual physical activity and an unhealthy weight status (Stodden et al. 2008; Lima et al. 2017).

A negative association between BMI and GMC, as well as a positive association between PF and GMC, was found in the present study. Further, there was a positive association between age-by-PF interaction and GMC. Both BMI and PF variables have previously been shown to be consistently related to GMC (Robinson et al. 2015; Cattuzzo et al. 2016). A higher BMI, specifically associated with higher body fatness, may impair the capability to move effectively, especially in tasks involving shifting and/or stability of the body in space, as in jumping and balancing tasks (Barnett et al. 2016). Additionally, adequate PF levels are linked to more effective coordination and control of movement (i.e. skill) as the development of both strength and GMC and performance are inextricably and biologically linked via the development of inter- and intra-muscular performance (Stodden et al. 2014; Cattuzzo et al. 2016; Henrique et al. 2018).

Geographical region also had a marked influence on GMC in this sample of Peruvian children. In a previous report, Bustamante Valdivia et al. (2015) showed that children from the rainforest had better physical performance in muscular power and flexibility tests, but youth from the high altitude region had higher cardiorespiratory fitness. Additionally, Chaves et al. (2016) reported that children living at high altitude and sea level were two times more likely to show low GMC than children from the rainforest. A possible explanation for our results may be related to the different climatic and environmental conditions of each region. In the sea level region, there is a high population density with serious problems with the built environment (e.g. traffic congestion and public security), which may contribute to the choice of more sedentary activities, such as watching television or playing games at home (Instituto Nacional de Salud 2005). The high altitude area, marked by a more severe climate, makes it difficult to participate in physical and sports activities while outdoors; in addition, the high altitude residents do not have an adequate leisure infrastructure that favours participation in activities that inherently promote GMC development. Residents in the rainforest, in turn, have a favourable tropical climate and environmental conditions for more active lifestyles, and they are able to diversify and develop their GMC and foundational motor skills associated with physical activity levels (Instituto Nacional de Salud 2005). We could not find a published paper that investigated the links between natural environments (sea level, rainforest or altitude) and children's/adolescents' GMC to make suitable comparisons with our results. Yet, previous research examining cross-country differences in GMC showed heterogeneity among countries. For example, Bardid et al. (2015) showed that Belgian youth outperformed Australians. Recently, Haga et al.

(2018), using data from Greece, Italy and Norway, reported that differences in motor competence were likely to be explained by physical activity levels, cultural policies, attitudes and habits toward movement.

This study is not without limitations. Despite the size of our sample, it is not representative of the Peruvian population. This implies caution in the generalisation of the results. Additionally, the inclusion of an objective measure of PA with accelerometers and/or pedometers could contribute to a better understanding of sibling resemblance in GMC and related correlates. However, logistical and financial difficulties made this unfeasible for the current study. The study also has several strengths that need to be highlighted. First, it covers siblings residing in three different geographic areas. Second, we used standardised training and measurement protocols to obtain highly reliable data. Finally, the use of a multilevel analysis model with individual and environmental data is meritorious because it addresses their interplay on GMC development.

In conclusion, our results showed statistically significant sibling similarity in GMC in Peruvian children, favouring SS pairs. Additionally, boys outperformed girls in GMC tasks and older children demonstrated higher GMC levels. Siblings with lower BMI, as well as those who were more physically fit, showed better GMC. Rainforest siblings had higher GMC than those from sea level and high altitude siblings were less coordinated than their sea level peers. These results reinforce that the expression of GMC is not only a function of genetic traits, but is also synergistically influenced by shared as well as unique experiences and environmental contexts. Therefore, when designing future intervention programmes at multiple levels (e.g. school, after school, family, etc.) to improve GMC in children and adolescents, care should be taken to account for the specificities of cultural and social settings of each geographical area, as well as considering the effects of sex, heterogeneity in weight status and physical fitness levels.

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