Correlations in parameters of balance between fathers and their adult sons

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Abstract

Background: The literature data suggest that balance control is genetically determined, however the data are inconsistent with respect to correlations in balance parameters among adult relatives. Therefore, the aim of the present study was to identify correlations between fathers and their adult sons in chosen balance parameters. Moreover, we tested how the relationships in balance between fathers and their adult sons change following fatigue.

Methods: The balance parameters were measured twice: before and immediately after the fatigue procedure (treadmill running to exhaustion) with the pedographic platform in two groups of relatives and correlated for 30 pairs father-adult son.

Results: The positive significant correlations were found for parameters describing deflection in the sagittal plane: the average deflection of center of pressure progression (COPP) and average value of COPP velocity in sagittal plane as well as the average value of velocity of COPP, the length of COPP trajectory and the surface area of the trajectory covered by COPP, both before and after the fatigue procedure. There were no significant correlations between lifestyle of participants and balance parameters.

Conclusions: In summary, our study found numerous correlations in balance parameters related to deflection in the sagittal plane between fathers and their adult sons. These correlations were not abolished by fatigue. Our results suggest that the ability to maintain balance is influenced by genetics. This conclusion can be useful in many sports in which the ability to maintain balance influence on sports score.

Background

Balance and human body orientation are dependent on multiple sources of afferent and efferent information about ongoing and intended patterns of movement and posture. Exposure to unusual forces and patterns of sensory feedback alters the normal relationship between patterns of alpha and gamma activation of antigravity muscles, muscle spindle activity, and movements of the body, which may evoke illusory feelings of motion and balance disorders (Lackner and Graybiel, 1984; Young, 2003). Maintaining balance is a process that involves multiple receptors; namely, the vestibular system and muscle proprioceptors (mainly muscle spindles in extensors). In addition, vision plays a part in posture maintenance (Gandevia, 1996; Gandevia et al, 2006; Chalmers, 2004; Proske, 2005; Wang et al., 2012). In the central nervous system (CNS), the brain stem structures (mainly vestibular nuclei) and cerebellum are involved in posture control. Equilibrium is one of the most important elements of each motor task, both for maintenance of stable body position (static equilibrium) as well as during movement (dynamic equilibrium) (Comerford and Mottram, 2001). Thus, the ability to maintain balance is a factor that influences motor skills and plays an important role in the prevention of injuries (Aras et al, 2018; Emerya and Pasanen, 2019).

Motor skills, including maintaining of balance and motor coordination, are a result of interactions between genetic factors and the external environment (Bouchard et al. 1997; Molly et al., 2009; Rankinen et al., 2006), although this issue is not yet completely understood. Many authors have posited that at least some coordination skills have a genetic basis (Frederiksen et al., 2002; Tiainen et al., 2004). The results of tests carried out on pairs of twins showed similarities in accuracy of movement, as well as in the ability to repeat the target force (Lyakh, et al., 2007). It should be emphasised that various testing methods can produce different results. In family studies based on the EUROFIT method ("flamingo balance"), which compared balance parameters between parents and their children, there was no significant correlation when the results of fathers and mothers were compared to the results of their sons and daughters (Jaworski et al., 2010). However, the paper did not detail how the measurements were made. The lack of correlation in this study might be due the comparison of adult parents with their children, whose motor skills were still under development as they matured.

It is known that lifestyle can also affect ability to maintain balance. Different forms of physical activity improve balance (Moreno-Segura et al., 2019 and Panou et al., 2018). On the other hand to low physical activity, excessive body weight, and BMI may impair balance in humans (Kovalek et al., 2019).

Muscle fatigue is known to modulate the proprioceptive and kinesthetic properties of the joints; it increases the discharge threshold of muscle spindles, weakens afferent feedback, and changes somatosensory input, thereby inducing deficits in neuromuscular control (Arliani et al., 2013). In addition, numerous studies have shown that muscle fatigue of the lower limbs significantly affects the stability of posture; for example, balance disorders were observed in football players after a match (Brito et al., 2012; Arliani et al., 2013). Deterioration of balance has also been observed in knee extensor fatigue caused by electrical stimulation (Chaubet and Paillard, 2012). Other studies have confirmed the impact of fatigue of the lower limbs on proprioception of the knee and injury incidence, and it is believed that disorders of neuromuscular control are the main mechanism (Hiemstra, et al., 2001). It is interesting and unknown whether the ability to maintain balance under fatigue is similar in related people. These data can be important in sports disciplines where maintaining balance in fatigue conditions plays an important role.

Aim of the study

Information from the literature is inconsistent with respect to correlations in balance parameters among adult relatives. Therefore, the aim of the present study was to identify correlations between fathers and their adult sons in basic balance parameters: dominant direction and deflection value, speed of movement of center of gravity, and size of area defined by trajectory. Muscle fatigue can impact on balance, therefore balance measurements were made both before exercise and under the influence of fatigue caused by running until exhaustion.

Methods

Participants

Thirty pairs of fathers and adult sons were selected. The mean basic characteristics of the fathers were age 49.6 ± 5.3 years, height 176.1 ± 4.6 cm, and weight 87.1 ± 9.6 kg. The mean basic characteristics of the sons were age 23.3 ± 3.7 years, height 179.9 ± 6.8 cm, and weight 78.6 ± 13.2 kg). All sons (tourism and recreation students) exercised for a total of 135 minutes per week, including gymnastics (45 minutes per week) and soccer. Based on the results of Fantastic Lifestyle Checklist (Heyward 2010), the lifestyle of fathers and sons was good and very good; respectively. None of the participant had contraindications for participation in the experiment, and their good health was confirmed by a medical doctor, who also supervised the experimental protocol.

Balance test

The ability to maintain body balance in a static standing position was measured with the PEL-38 Midi-Capteurs electronic pedobarograph and a computer image analyser with TWINN 99 software (France). The dimensions of the plate were 500 mm × 500 mm, and it contained 1024 sensors. The platform was connected to a computer. The TWINN 99 software was used for processing and archiving static posture parameters, which were then subjected to statistical analysis. Before each measurement, the device was calibrated and the participant was informed about the experiment procedure. During the test, each participant stood on the platform on both feet for 60 seconds; his feet were placed at a distance of about 10 cm from each other on the appropriate lines on the platform. The participant performed the tests without shoes, with eyes closed, and with upper limbs positioned alongside the trunk. The center of pressure (COP) was measured. COP was characterised by the following parameters: Wx, average deflection of center of pressure progression (COPP) alongside axis x (mm); Wy, average deflection of COPP alongside axis y (mm); asx, average value of COPP velocity in sagittal plane (mm·s); asy, average value of COPP velocity in frontal plane (mm·s); aq, average value of COPP velocity (mm·s); pl, length of COPP trajectory (mm); and pa, surface area of the COPP trajectory (mm^2).

Fatigue procedure

After the balance test, each participant performed a running test on a treadmill Trackmaster TM310 (USA). During this test, the maximal oxygen uptake (VO_2 max) was determined. Breath-by-breath oxygen uptake was continuously recorded with the Oxycon Mobile ergospirometric system (Viasys Healthcare, Germany). Heart rate was continuously recorded during the test with the portable heart rate telemetry device Polar Sport Tester (Finland). The test was incremental; all participants started at a 4.0 mph running speed, which was increased by 0.5 mph every 2 minutes until the maximal level of recorded parameters was achieved. When the participant could not continue the test because of fatigue, the test was stopped. Three criteria for task termination were taken into consideration: respiratory exchange ratio > 1.1, oxygen consumption plateau despite of running speed increase, obtaining maximum heart rate in relation to age of participant. When two from three mentioned above criteria were met and participant was not able to run the fatigue test was completed. Immediately after the fatigue procedure, the participants repeated the balance test according to the methodology described above.

Questionnaire

To asses lifestyle of subjects they completed the Fantastic Lifestyle Checklist questionnaire (Heyward 2010). The point score obtained in the questionnaire allows to assess lifestyle of each subject in five ranges: needs improvement (0–34 pts), fair (35–54 pts), good (55–69 pts), very good (70–84 pts), and excellent (85–100 pts).

Statistical analysis

To confirm a normal distribution of the data the Shapiro–Wilk test was used. Descriptive statistics, including means and standard deviations, were calculated. Differences between the same parameters noted in the groups were tested with one-way ANOVA. If differences were detected, the Scheffe post hoc procedure was used to determine where the differences occurred. Because for all studied properties a normal distribution of data was confirmed, Pearson correlation coefficients were determined for selected variables achieved by fathers and their sons. P values of < 0.05 were considered significant.

Results

The differences in all balance parameters noted in fathers and their sons were not significant (both before and after exercise).

The average deflection of COPP in the front–rear direction (Wx) was 4.9 ± 1.9 mm in the group of fathers and 4.5 ± 1.9 mm in the group of sons before exercise. Later, due to fatigue, both values increased accordingly to 6.7 ± 3.7 mm and 7.3 ± 3.5 mm in the father and son groups, respectively. The correlation in Wx between the fathers and sons was significant both before and after fatigue (Figure 1).

(figure 1 about here)

Deflection of COPP in the right–left direction (Wy) in the group of fathers was 5.7 ± 1.8 mm before exercise and 8.6 ± 4.4 mm after exercise, while it was 4.9 ± 2.0 mm for sons before exercise and 10.2 ± 8.4 mm after exercise. There were no significant correlation between the results for fathers and their sons ($r = -0.11$ and $r = 0.19$ before and after exercise, respectively).

There was a positive correlation in the average velocity of COPP (aq) along both axes between fathers and sons, and the correlation coefficients before and after exercise were significant (Figure 2). Significant correlations were also observed for the average velocity of COPP along the x axis (asx), both before and after exercise (Figure 3). In contrast, correlations of COPP velocity in the frontal plane (asy) were low and statistically insignificant. A significant correlation was also found for path length (pl) (Figure 4) and the surface area outlined by the trajectory (pa) of COPP for fathers and their sons, both before and after the running test (Figure 5).

(figures 2-5 about here)

All tested balance parameters increased significantly after fatigue procedure, both in the fathers and their sons.

It is worth noting that the correlations in analyzed parameters between the fathers and young control group were not significant both before and after fatigue (except of average velocity of COPP along the y axis after exercise – Table 1).

(table 1 about here)

Based on the results of Fantastic Lifestyle Checklist (Heyward 2010), the lifestyle of fathers and sons was good (68 pts) and very good (75 pts); respectively. Significant correlation coefficient was found for the lifestyle of fathers and their sons; r = 0.46. However, there were no significant correlations for lifestyle score and balance parameters (Table 2).

(table 1 about here)

Discussion

The results of our study demonstrate that there are significant correlations between the balance parameters based on frontal plane deflections between adult relatives. Together with the results provided in an accompanying paper (Bezulska et al., 2018), these observations extend what is known about correlations within families with respect to motor skills related to proprioception from muscle receptors and vestibular organs.

Before the study we supposed that correlations in balance between fathers and sons could result from genetic and lifestyle-related factors (social factors, habits, physical activity) (Kovalek et al., 2019, Moreno-Segura et al., 2019, Panou et al., 2018). Our research showed that there was a significant correlation between the lifestyle of fathers and their sons. However, there were no significant correlations between the fathers lifestyle and balance and between the sons lifestyle and balance. Given that it seems that the ability to maintain balance predominantly is genetically determined.

There are two possible reasons for the presence of correlations in balance parameters among relatives. First, it is possible that functional efficiency of the sensory system associated with balance (i.e., vestibular organ and/or muscle spindles) is hereditary. Second, it is possible that the functional efficiency of CNS structures (mainly of vestibular nuclei, cerebellum, and spinal cord) that are active while maintaining balance (Welch and Ting, 2014) has a genetic component.

The range of the equilibrium parameters that we investigated increased after prolonged running. It is known that muscle spindle afferents associated with the control of body position are modulated during activity. Moreover, muscle length changes during consciously performed physical activity, as well as during automated maintenance of vertical posture (Winter et al., 2005; Ansems et al., 2006; Allen et al., 2007, Allen et al., 2010); this probably modulates the activity of muscle receptors. These mechanisms may partly explain the observed deterioration in balance while under the influence of fatigue.

Physical exercise and fatigue did not affect the examined correlations, although the studied balance parameters increased (Figs. 1–5). This observation is in concordance with data from the literature (Brito et al., 2012; Chaubet and Paillard, 2012; Arliani et al., 2013). The correlation coefficients increased, most likely as an effect of enlargement of the ranges of the analysed parameters and the similar degree to which fatigue influenced both fathers and sons. On the other hand, the increase in tested values may be explained by post-fatigue systemic changes (e.g., increased heart rate, uneven breathing, and discomfort associated with severe sweating), as well as by altered muscle receptor activity during exercise or slow adaptation of receptors after physical activity (Allen et al., 2010; Walsh et al., 2004, Walsh et al., 2010).

In the described experiments, the subjects maintained steady footing on the platform; thus, any movement of the body caused tilting of the head in different directions in the horizontal plane. However, the significant correlations found in the present study concerned parameters related to movements in the anteroposterior axis, most probably due to the lateral support of the body on both feet. The dominance of deflections in the anteroposterior axis of COPP has been confirmed in numerous studies (Błaszczyk and Orawiec, 2011). Many authors have stressed the significance of the plane in which the movement occurs (Ansems et al., 2006; Allen et al., 2007; Allen et al., 2010; Bekrater-Bodmann et al., 2012), which is associated with differences in proprioceptive information that are dependent on gravity (Winter et al., 2005).

In many sports the ability to maintain balance directly affects the sport results. Our results suggest that the ability to maintain equilibrium is hereditary, that conclusion can be useful to sport selection process in some disciplines, e.g. in shooting, archery. Moreover, the results of our study indicated that physical exercise and fatigue did not affect the examined correlations in measured balance parameters between fathers and their sons (values of correlation coefficients remained statistically significant). Thus, our results may be useful also to sport selection process, e.g. biathlon, ice skating, gymnastics.

Conclusions

Our study found numerous correlations in balance parameters related to deflection in the sagittal plane between fathers and their adult sons. These correlations were not abolished by fatigue. Our results suggest that the ability to maintain balance is influenced by genetics.

Declarations

Ethics approval and consent to participate

All participants provided written informed consent to participate in the study, and all procedures were approved by the local ethical committee (Ethics Committee at the Adam Mickiewicz University in Poznan, Poland), with approval based on the Declaration of Helsinki.

Consent for publication

The manuscript does not contain any individual person’s data in any form.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

The authors declare that did not receive financial support to conduct the research.

Authors' contributions

MN - performed the research in laboratory and was a major contributor in writing the manuscript

AB - was responsible for subjects recruiting and performed the research in laboratory

ZA – cooperation in study design, statistical analysis

JC - was responsible for the design of the study and was a major contributor in writing the manuscript

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Tables

Table 1. Correlation coefficients before and after exercise between fathers and control group.

	wx	wy	aq	asx	asy	pl	pa
rest	-0.22	0.32	0.21	-0.19	0.28	0.09	0.19
fatigue	-0.30	-0.02	0.01	-0.28	-0.39*	-0.04	0.09

Abbreviations:

* significant correlation,

wx - average deflection of COPP in the front–rear direction

wy - deflection of COPP in the right–left direction

aq - average velocity of COPP

asx - average velocity of COPP along the x axis

asy - average velocity of COPP along the y axis

pl - trajectory path length of COPP

pa - trajectory surface area of COPP

Table 2. Correlation coefficients between lifestyle points and balance parameters.

		wx	wy	aq	asx	asy	pl	pa
father	rest	0,15	0.20	0,35	0,19	0,04	0,25	0,25
	fatigue	0,10	-0.25	0,22	0,20	0,08	0,21	0,19
son	rest	-0,16	0,34	0,27	-0,26	0,16	0,09	0,27
	fatigue	-0,06	-0,05	0,01	-0,03	-0,16	0,02	0,11

Abbreviations: as in table 1

Figures

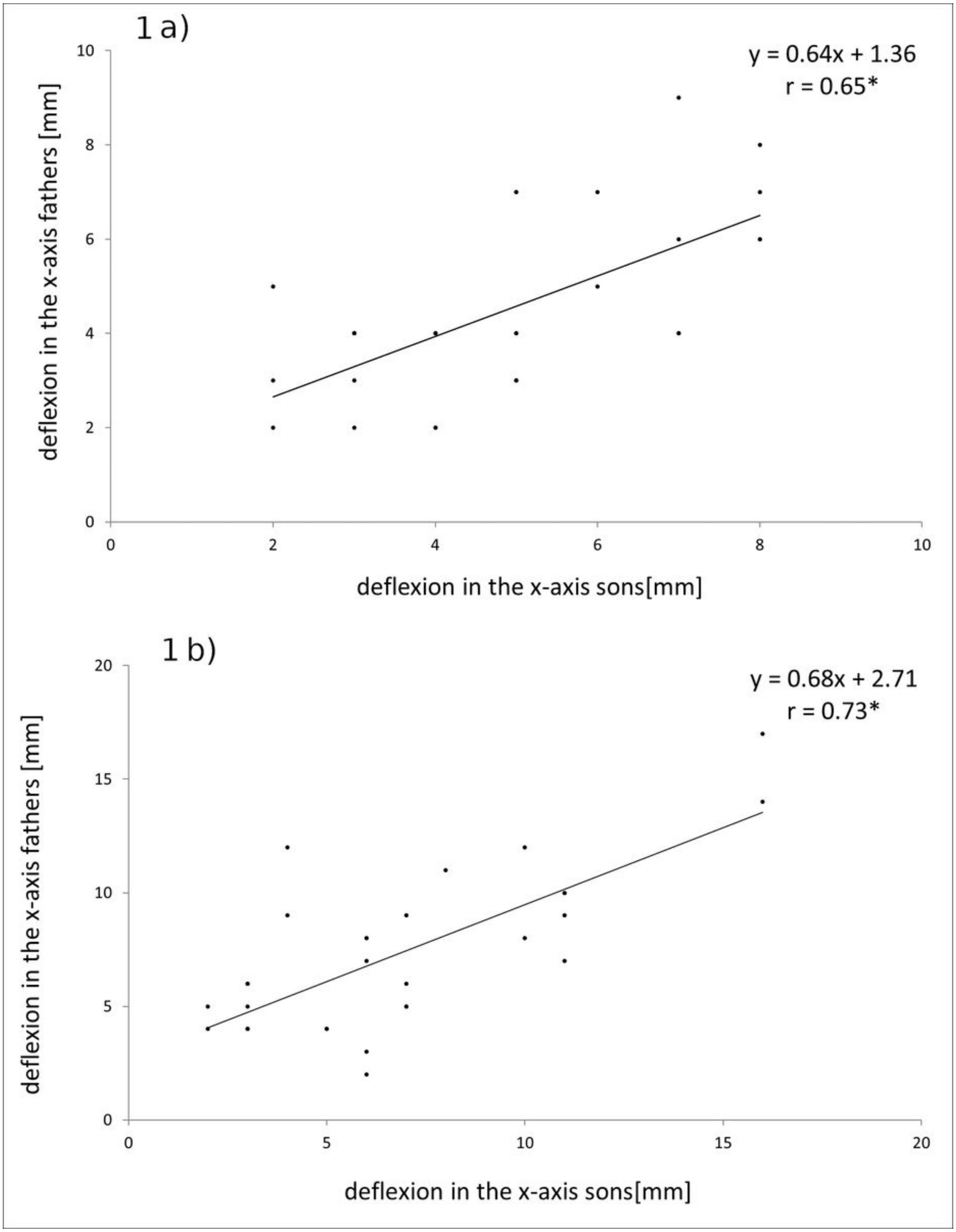

Figure 1

Correlations in the mean deflection center of pressure in the direction of the sagittal plane (Wx) between fathers and their adult sons, both before (a) and after (b) exercise. Each point corresponds to data from one father–son pair. Equations for the regression lines appear over the plot. * Correlation significant (P < 0.05).

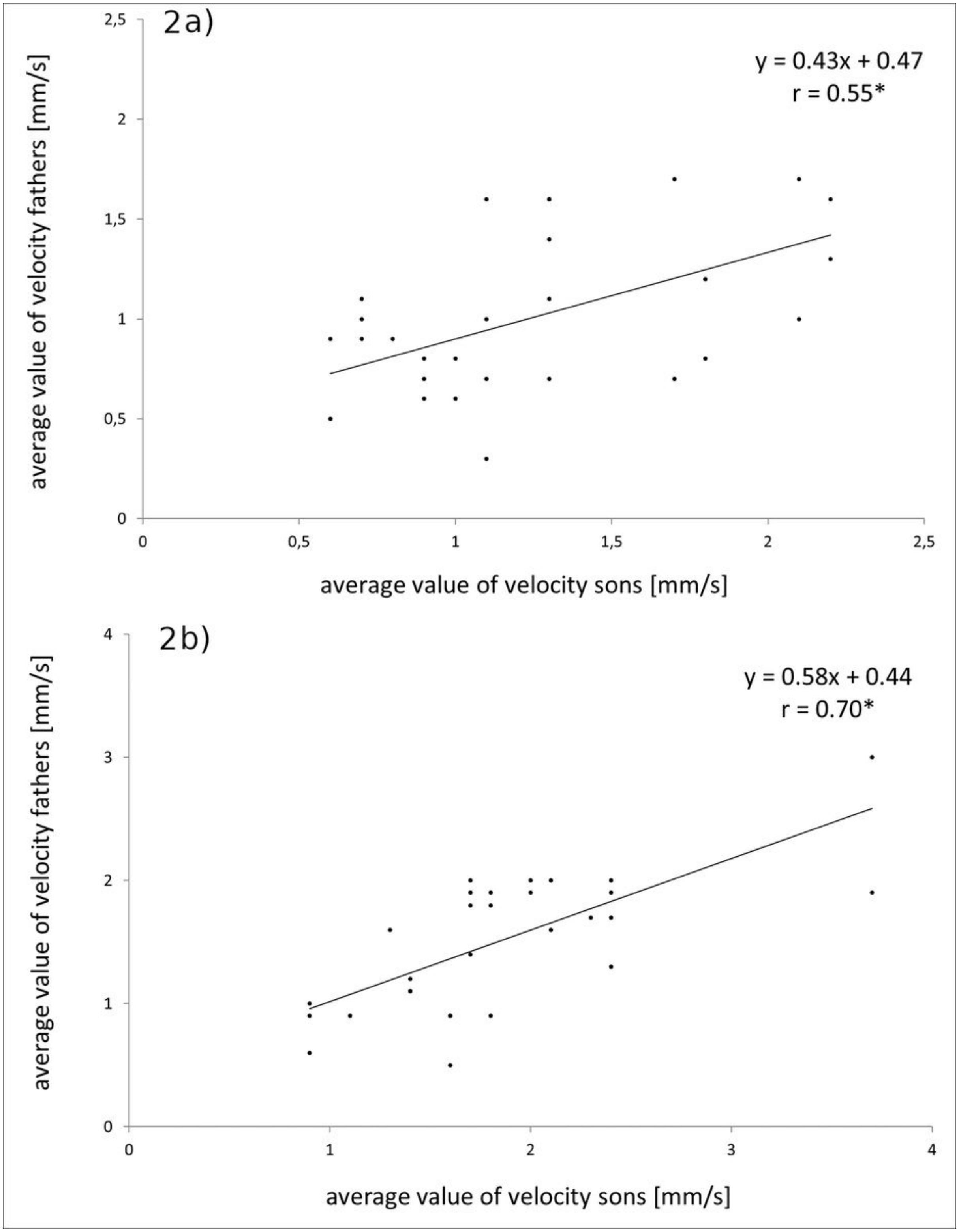

Figure 2

Correlations in average velocity (aq) of COPP between fathers and their sons before (a) and after (b) exercise. Each point corresponds to data from one father–son pair. Equations for the regression lines appear over the plot. * Correlation significant ($P < 0.05$).

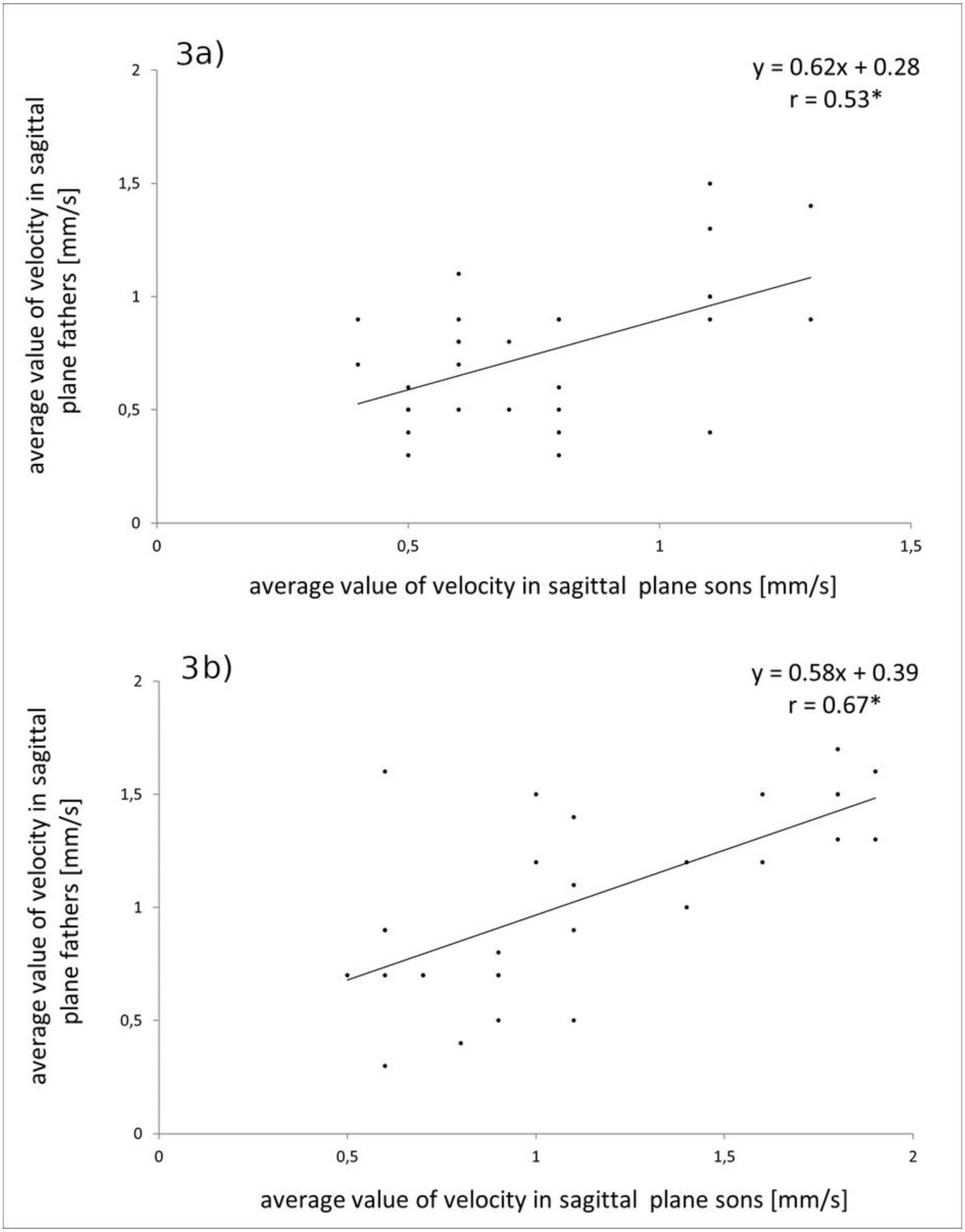

Figure 3

Correlations in average velocity of COPP in the sagittal plane along the x axis (asx) between fathers and their sons before (a) and after (b) exercise. Each point corresponds to data from one father–son pair. Equations for the regression lines appear over the plot. * Correlation significant ($P < 0.05$).

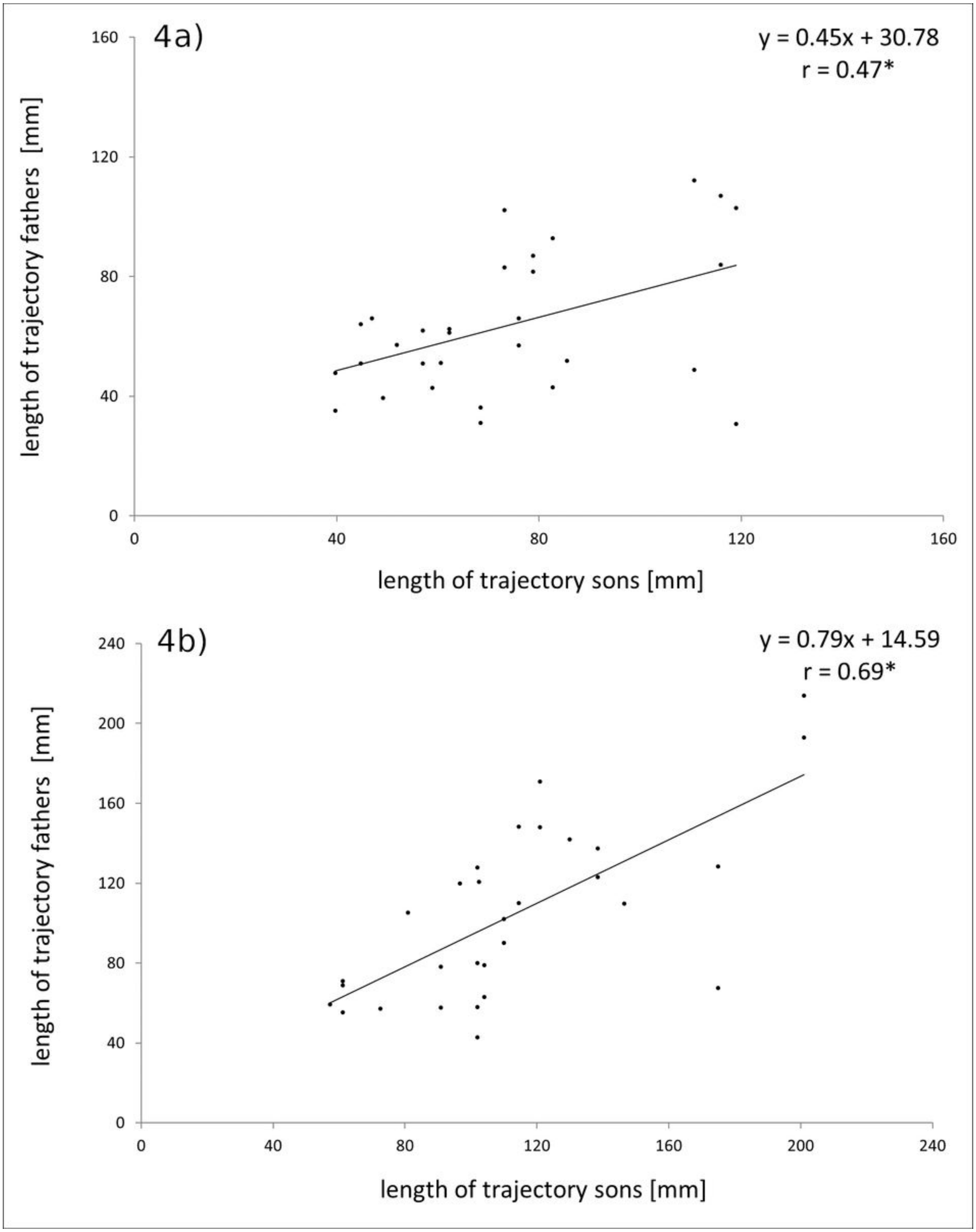

Figure 4

Correlations in trajectory path length (pl) of COPP between fathers and their their sons before (a) and after (b) exercise. Each point corresponds to data from one father–son pair. Equations for the regression lines appear over the plot. * Correlation significant ($P < 0.05$).

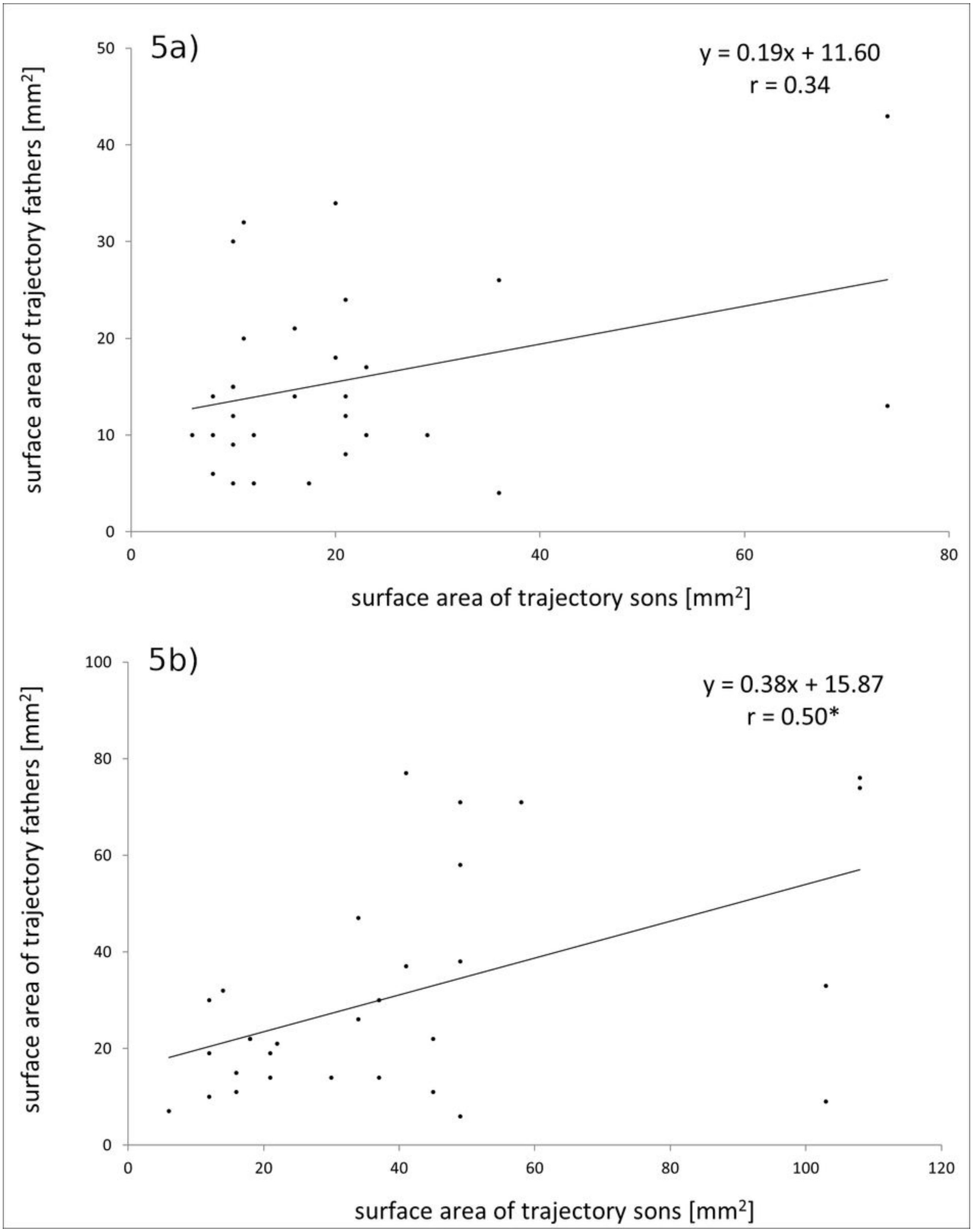

Figure 5

Correlations in surface area of the COPP trajectory (pa) for fathers and their sons before (a) and after (b) exercise. Each point corresponds to data from one father–son pair. Equations for the regression lines appear over the plot. *Correlation significant ($P < 0.05$).