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Differences in Sensorimotor Feedback Performance by Body Weight in 12- to 15-Year-Old Adolescents

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Abstract

Background: The field of sensorimotor feedback is still a young area in science. In several studies, it has been observed that with increasing exercise intensity, motor performance decreases in overweight and obese individuals compared to normal weight individuals, but in the area of sensorimotor feedback performance, the data is still very limited. **Aim:** The present study investigates the association between body mass index (BMI) and sensorimotor feedback performance in Austrian adolescents. **Methods:** In a cross-sectional study, 12- to 15-year-old adolescents (N = 294) were recruited from 5 schools in Tyrol (Austria). Using the reference system according to Kromeyer-Hauschild et al. (2001), BMI percentiles were determined, and participants were categorized into four weight categories: underweight, normal weight, overweight, and obese. Sensorimotor feedback performance was assessed using the MFT® Challenge Disc. Differences in sensorimotor feedback between weight categories were determined via Kruskall-Wallis test for independent samples with SPSS 28.0. **Results:** Of the 294 adolescents (48.6% female), 16.3% were overweight and 7.2% were obese. The results show that underweight and normal weight adolescents do not differ in sensorimotor performance, while performance was significantly worse in overweight and obese adolescents ($p < 0.05$). **Conclusions:** These results emphasize the importance of diverse movement experiences that not only address physical fitness but also coordinative abilities in adolescents, particularly those with excess body weight.

Keywords

Sensorimotor Feedback, Balance, Overweight and Obesity, Youth, Health, Motor Ability, School

1. Introduction

Physical fitness, motor abilities and adequate physical activity are considered important determinants of physical and psychosocial health in children and adolescents. Improved physical fitness has been associated with a reduced risk for various chronic diseases, particularly in overweight and obese youth in addition to the well-established beneficial association between physical fitness and cardiovascular disease risk in adults (Millard-Stafford et al., 2013; Stodden et al., 2017). In addition, age-appropriate well-developed motor skills are crucial for learning sport-specific skills and facilitate the engagement in various forms of physical activity (Godoy-Cumillaf et al., 2022; Ortega et al., 2011). However, due to the decline in physical activity, an increasing number of children and adolescents exhibit reduced physical fitness and motor deficits (Greier & Drenowatz, 2018; Guthold et al., 2020). This is often associated with an increase in sedentary leisure time activities (e.g., media consumption) (Kaiser-Jovy et al., 2017; Bull et al., 2020; Oduro et al., 2023). Along with declining physical fitness due to physical inactivity there has been an increase in childhood and adolescent obesity (Tremblay, 2012; Biswas et al., 2015; Patterson et al., 2018; Chastin et al., 2019).

Even though the prevalence of overweight has been relatively stable in certain regions (Wabitsch et al., 2014; Sigmund et al., 2023), globally, there has been a continuous increase in overweight and obesity over the last two decades (Lier et al., 2021). Thus, overweight and obesity continue to be a prevalent problem in Western industrialized countries, associated with higher current and future disease risk (Castetbon & Andreyeva, 2012; Drenowatz & Greier, 2018; Faigenbaum et al., 2018; Genovesi et al., 2023).

The sharp increase in childhood and adolescence is particularly worrying. In Austria, for example, the number of overweight and obese children and adolescents is currently estimated to be over 25%, depending on the region (Felder-Puig et al., 2023), and in some European countries the prevalence of overweight among children has even risen to over 40%, thus reaching alarming proportions (WHO, 2016). In addition to the health risks, overweight and obesity are often associated with deficits in motor competence. For example, national and international studies show a negative correlation between BMI and physical fitness (Hardy et al., 2012; Greier & Drenowatz, 2018; das Virgens Chagas et al., 2021). In addition to poor physical fitness, overweight and obesity have been associated with a lower coordinative ability; particularly motor balance (Guzmán-Muñoz et al., 2023; Raschner et al., 2011). Several studies (Hue et al., 2007; Kejonen et al., 2003) have also shown a negative influence of overweight on posture. For example, excess body weight can alter body geometry, which results in a forward shift of the body's center of gravity (Jeong et al., 2021). Furthermore, it can lead to decreased sensitivity of the mechanoreceptors of the sole of the foot and impaired gait mechanics (Mignardot et al., 2013). Overweight and obesity have also been associated with a deficit in sensory integration processes in postural control tasks (Maktouf et al., 2018). Given the importance of a well-developed balance ability to ensure an adequate quality of a movement along with the impact on the prevention of accidents, motor balance should be promoted early and in a targeted manner (Araujo et al., 2022; Godoy-Cumillaf et al., 2022). Specifically, sensorimotor feedback, which refers to the various stimuli that provide information on the body's situation and position (Goodworth et al., 2023), appears to be critical in this aspect.

The aim of the present study, therefore, was to investigate potential differences in static and dynamic balance ability of overweight and obese 12 - 15-year-old adolescents compared to their normal weight peers.

2. Materials and Methods

The present cross-sectional study investigates sensorimotor balance in 12- to 15-year-old secondary school students as this age group has been shown to be particularly vulnerable for accelerated weight gain (Schienkiewitz et al., 2018). Further, lifestyle patterns established during adolescence have been shown to affect CVD risk during adulthood (Schnermann et al., 2021). For this purpose, five middle schools (7^{th} and 8^{th} grade) in Tyrol (Austria) were randomly selected and asked to participate in the study. From the five schools, 294 adolescents could be recruited. The study protocol was approved by the participating schools and the school board. Legal guardians of the participants were informed by letter and provided written consent.

2.1. Study Protocol

Balance tests were performed between October and November 2022 during regular school hours in school gymnasiums. First, height and weight were measured in sportswear without shoes (barefoot). Body height was measured with a mobile stadiometer (SECA® 213, Hamburg, Germany) with an accuracy of 0.1 cm and body weight was measured with a calibrated scale (SECA® 803, Hamburg, Germany) with an accuracy of 0.1 kg. Based on these data, body mass index (BMI, kg/m^2) was calculated and converted to BMI percentiles using the BMI reference system of Kromeyer-Hauschild et al. (2001). Within this reference system, adolescents are considered normal weight if their BMI is between the 10th and 90th percentiles. Values below the 3rd percentile are considered anorexic, and values between the 3rd and 10th percentiles are classified as underweight. A BMI between the 90th and 97th percentiles is considered as overweight and values above the 97th percentile are considered obese. Since no participant had a BMI below the 3rd percentile, BMI values were divided into the four BMI groups of underweight, normal weight, overweight, and obese for the analysis.

2.2. Test Instrument

The MFT® Challenge Disc sensorimotor feedback training device (MFT Bodyteamwork GmbH, Vienna, Austria) was available as test device. This consists of a round base plate with a diameter of 420 mm and is connected to a bottom plate by four rubber buffers. Due to this construction, the plate can be tilted in all planes. The maximum tilt angle is 12˚. Balance adjustments of a person standing on the plate lead to tilting movements of the standing surface, which are detected by a three-dimensional tilt sensor. The measuring range of the sensor is 20˚, with a measuring accuracy of 0.5˚ and a sampling rate of 100 Hz. Data are read into a software via a USB cable (Raschner et al., 2008). On a screen positioned in front of the exercising person, the balance movements are visualized by the software by means of a control circuit. This control circle is to be kept in the given target circle for as long as possible by fine motor regulations. The tests were all performed at the easiest difficulty level (=level 1). Each exercise test lasts for 20 seconds with a standardized pause of ten seconds to avoid neuromuscular fatigue between tests. A maximum of 100 points can be achieved for each of the nine exercises, allowing a maximum total score of 900 points. The longer the control circle can be held in the specified target circle, the higher the score achieved. At the end of the test, the total score achieved is displayed in points (maximum 900) and also the static and dynamic balance in percent. Here, for the dynamic balance exercises, the percentage value was calculated from 600 possible points, and for the static ones, the percentage value achieved from a maximum of 300 points was quoted (Raschner et al., 2011). The MFT® Challenge Disc is similar in function to the test device for sensorimotor balance "Biodex Balance Systems"®. This device quantifies the dynamic and static balance ability of test subjects on an unstable surface and provides objective, valid and reliable measurement data (Arnold & Schmitz, 1998).

2.3. Test Implementation

Students were tested individually and barefoot in a segregated room of the gymnasium (equipment room) to ensure optimal concentration. The test procedure was explained, and a familiarization test was performed before the actual testing. The test subjects stood on the test apparatus with both feet on the ground and with their knee joints slightly bent, with the foot positioning (slight straddle position) dictated by a mark on the stand plate.

2.4. Statistical Analyses

Interval-scaled data (anthropometric data and score values) were reported as mean and standard deviation (MW ± SD). Group subdivisions by BMI were expressed as absolute (N) and relative (%) frequencies. Frequency differences were collected using the chi-square test, and differences between the four BMI groups were calculated using Kruskall-Wallis test for independent samples. Specific group differences were analyzed by post hoc test with Bonferroni correction for multiple testing. All statistical calculations were performed using SPSS 28 (IBM Corp., Armonk, NY).

3. Results

The mean age of the participants was 13.4 ± 1.1 years and the mean BMI was 21.0 ± 3.3. According to the reference values used by Kromeyer-Hauschild et al. (2001), of the 294 participants (48.6% female), a total of 7.4% (n = 22) were underweight, 69.1% (n = 203) were normal weight, 16.3% (n = 48) were overweight, and 7.2% (n = 21) were obese (Table 1).

There were no significant differences in total score as well as dynamic and static balance performances between boys and girls ($p > 0.2$). However, the performances of overweight and obese adolescents were significantly different ($p < 0.01$) from their underweight and normal weight peers. A significant difference ($p < 0.05$) in overall balance performance between overweight and obese adolescents was also observed in favor of the overweight (score 394 vs. 594). In contrast, no significant differences ($p > 0.05$) were found between underweight and normal weight adolescents (Figure 1).

Table 1. Characteristics for the different BMI groups; Mean value (M) and Standard Deviation (SD).

Characteristics		Under weight	Normal weight	Overweight	Obese	Total
Age (years)	M	13.5	13.15	14.46	13.67	13.43
	SD	0.85	0.93	0.89	1.06	1.05
Gender	Female n (%)	16 (5.4)	98 (33.3)	22 (7.5)	7 (2.4)	143 (48.6)
	Male n (%)	6 (2.0)	105 (35.8)	26 (8.8)	14 (4.8)	151 (51.4)
Height (cm)	M	162.8	160.37	164.25	164.05	160.91
	SD	11.78	8.21	9.25	4.01	8.75
Weight (kg)	M	39.88	49.38	66.24	71.23	53.06
	SD	6.27	7.16	7.41	5.11	11.01
BMI	M	14.7	19.45	24.65	27.81	20.54
	SD	0.19	1.73	0.61	0.81	3.48

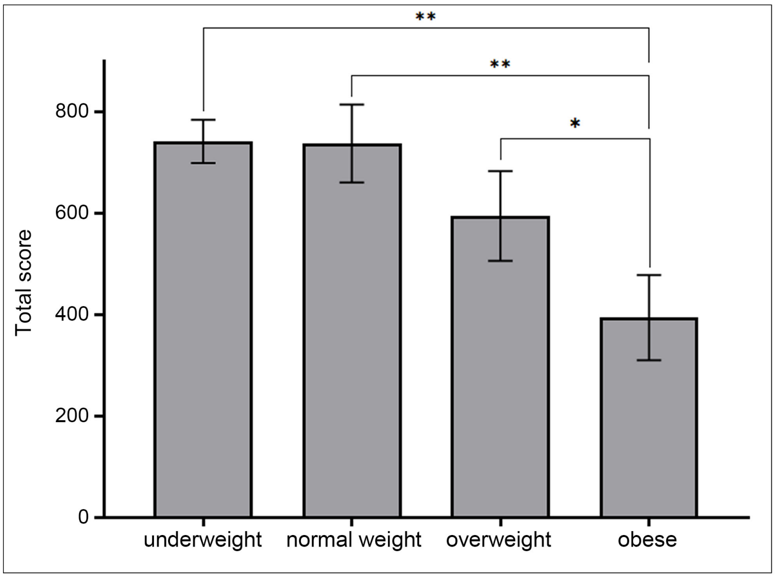

Figure 1. Total scores of adolescents as a function of weight classes (obese differ highly significantly from normal weight and underweight; ($p < 0.001$).

Looking at the results of the dynamic and static balance performances, in both tests the obese adolescents scored significantly lower than the underweight and normal weight BMI groups ($p < 0.01$). While the results in the dynamic balance test did not differ between obese and overweight subjects ($p = 0.44$), the obese group had significantly ($p < 0.01$) lower scores compared to the overweight group in the static balance tests (Figure 2).

4. Discussion

In the present study, 294 twelve- to fifteen-year-old adolescents from five Tyrolean middle schools were divided into four weight categories using German reference values (Kromeyer-Hauschild et al., 2001) and their sensorimotor feedback performance was recorded using the MFT® Challenge Disc.

The overweight and obese adolescents showed a significantly lower sensorimotor feedback performance in all tests (total score, static and dynamic balance performances) compared to their non-overweight peers. These results are consistent with the statements of other authors (Graf et al., 2004; Greier & Ressle, 2012; das Virgens Chagas et al., 2021) regarding the lower motor performance of

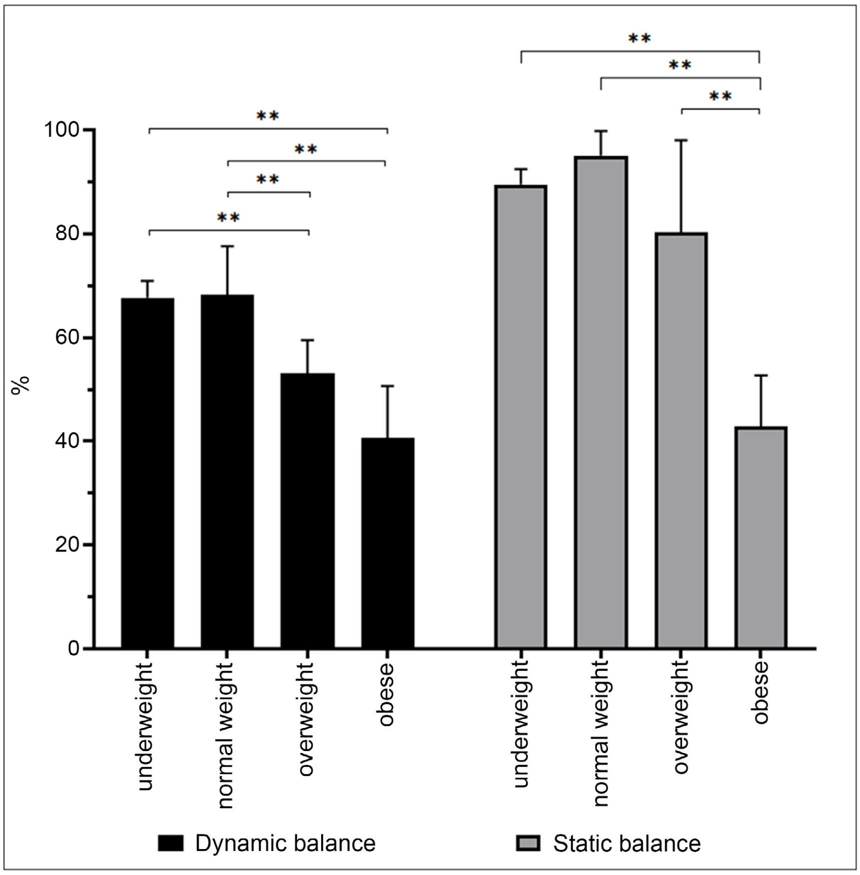

Figure 2. Test performances for the dynamic and static balance tests, broken down by weight class. The Obese and Overweight BMI groups have significantly lower scores on both the static and dynamic balance tests than subjects in the Underweight and Normal Weight BMI groups ($p < 0.05$).

overweight and obese individuals. In the study by Greier and Ressle (2012), obese 11- to 15-year-old students were also assessed for sensorimotor feedback performance using the MFT® Challenge Disc. As in the present study, the obese test takers performed significantly worse than their normal-weight counterparts on both the total score as well as the dynamic and static test domains.

In isolated static balance tasks, overweight and obese children and adolescents do not necessarily have a low level of performance according to a study by Bappert et al. (2003). Thus, in their study, no significant differences could be found in overweight children in the one-leg stand (static balance) compared to normal weight children. In our study, however, this could not be confirmed, as obese and overweight adolescents also performed significantly worse than normal weight participants in static balance tasks. A possible reason for these inconsistent results could be the use of different test devices.

It may, therefore, be suspected that increased body weight negatively affects coordinative abilities. Lack of "movement experiences" in everyday life could be one of the causes for low physical fitness and motor competence, because the body composition resulting from excess weight often impedes performance as well as the learning of motor skills (Drenowatz & Greier, 2018; Drenowatz & Greier, 2019). Recent studies also show that, in addition to cardiorespiratory and metabolic impairments, damage to the peripheral nervous system, known as neuropathy, is one of the most common complications of obesity. Such peripheral nervous system disorders can also lead to motor function impairments (Bonomo et al., 2022).

The testing device used in this cross-sectional study provided adolescents with visual feedback on their static and dynamic sensorimotor balance performance. Good balance ability is a basic requirement for almost all activities in daily life. Limitations in balance ability often result in a higher risk of falls and associated subsequent injuries (Raschner et al., 2008). Xiang et al. (2005) showed in their study that the risk of accidents was twice as high in obese people compared to normal weight people.

Since overweight and obesity can also frequently lead to psychosocial restrictions and thus also to a lack of engagement in leisure time physical activity and club sports, overweight people are not infrequently regarded as outsiders by their peers of the same age. As a result, they may lose interest in sports and exercise and suffer from low self-esteem (Kaspar et al., 2003). Psychological inhibitions, lack of motivation, self-uncertainty, and passive leisure activities, such as media consumption cause them to "withdraw" from leisure time physical activities. This can quickly lead to losses in motor competence, which in turn accelerates the vicious cycle of low physical activity, increased body weight and poor motor competence (Weineck, 2007).

The results of the present study underline the importance of motor abilities for children and adolescents. In order to ensure adequate motor development a variety of physical activity experiences should be offered at a young age, with a particular focus on overweight and obese children and adolescents.

5. Strengths and Limitations

BMI, which was used to define weight groups does not differentiate between muscle mass, bone mass and body fat and, therefore is not an ideal indicator for body composition (Moss et al., 2007). Nevertheless, BMI has proven to be a feasible and economical measure for body composition in childhood and adolescence. Due to the cross-sectional nature of the study, several important questions, such as tracking of body weight and balance abilities over time cannot be answered (Baird et al., 2005). Despite these limitations, it should not go unmentioned that data on adolescent sensorimotor feedback performance as a function of weight status have been scarce. Therefore, the results of the present study can provide viable information for preventive measures to be set at an early stage. The testing device used in this study (MFT® Challenge Disc) allows for improved objectivity and better quantifiability compared to conventional simple balance testing devices (e.g., T-rail for single-leg stance, Balance Disc).

6. Conclusion

The present study shows that compared to underweight and normal-weight adolescents, overweight and obese adolescents have lower balance abilities. These results suggest that a targeted promotion of physical activity, including balance activities, in early school age is warranted, with special attention to students at risk of overweight and obesity. Since the foundation for an active lifestyle is laid in early childhood, which positively influences physical activity behavior further in life, schools are the ideal setting for intervention measures in addition to the parental home, since everyone can be reached here.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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