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Posted Date: 3 February 2026

doi: 10.20944/preprints202602.0186.v1

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Is BMI a Determinant of Balance in Injury Prevention in Adolescents?

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Abstract

Background: Balance is a fundamental ability that ensures stability by maintaining the body's center of mass within its base of support and prevents injuries. It plays a crucial role in the progression of motor development during adolescence, influencing coordination, posture, and movement efficiency. Understanding the mechanisms and factors affecting balance can contribute to improved training methods and performance outcomes in both general and sports-specific contexts. BMI, gender, and sport type parameters that could affect balance in adolescent athletes were investigated. **Methods:** A total of 311 orienteering, volleyball, basketball and tennis players (mean age=15.29±4.75 years, mean body mass index (BMI)=20.31±3.28 kg/m2) aged 10-17 years were included in the study. Tanita BC418MA (Tanita, Japan) device was used for body weight assessment and BMI was calculated. Y-balance test was used for dynamic balance assessment. **Results:** BMI was associated with Y-balance test parameters on the dominant side of the athletes (p<0.005). Overweight athletes have worse balance parameters than normal BMI. The balance parameters of girl athletes were better in posteromedial (p=0.001) and posterolateral (p=0.021) directions, but less in anterior (p=0.029) direction than boy athletes. Balance parameters of orienteering athletes were found to be better than other sports branches (p<0.005). **Conclusions**: High BMI can impair balance in developing adolescent athletes, potentially increasing the risk of injury and affecting performance. Therefore, identifying the factors that influence balance is essential for optimizing athletic ability and implementing effective injury prevention strategies.

Keywords: adolescent; athletes; body mass index; balance

Introduction

An important step in preventing sport injuries is to identify modifiable risk factors. Commonly reported risk factors for sport injuries include muscle strength imbalances, balance problems and increased body mass index (BMI) [1,2]. Balance is the body's ability to create stability by maintaining the center of mass within the base of support [3]. To achieve this ability, data obtained from visual, auditory, and proprioceptive senses are processed. Maintaining posture during movement and executing complex movements in a coordinated manner require the coordinated function of these systems [4]. The proper formation of the motor response depends on two fundamental factors: sufficient muscle strength and a healthy neuromuscular system [4]. Balance is one of the physical parameters that affect sports performance in athletes [3]. In sports that involve ball control, acceleration, and sudden turns, maintaining postural control is crucial. Many studies have attempted

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to identify variables related to static balance and dynamic balance to predict lower extremity injuries in athletes [1,5].

Overweight and obesity have become widespread global health concerns. Adolescent with excess weight are likely to remain overweight into adulthood, increasing their risk of various injuries [6]. Body mass index (BMI) measurement is a frequently used assessment method for determining health status in both athletic and non-athletic populations [7]. Determining the anthropometric characteristics of athletes provides information on whether they are structurally and functionally suitable for their respective sports [8]. Many studies has shown that adolescent athletes with high BMI values are more likely to sport injuries [9,10]. Anthropometric characteristics have been shown to be associated with success in sports and prevention injuries [11].

Studies have indicated that individuals with high BMI need to make greater postural adjustments to maintain balance [12]. In individuals with high BMI, the center of mass shifts forward, making it more difficult to maintain balance [13]. Additionally, a relationship has been demonstrated between balance, athletic performance, and injury risk [2,14]. Ankle injuries have been reported to occur more frequently in athletes with high BMI [1]. Sports activities require adequate muscle strength and motor coordination to generate high levels of force. There is a lack of prospective studies investigating a multitude of risk factors for injuries in the adolescent athletes within a variety of sports. Additionally, there is a lack of studies investigating relationship for males and females separately.

Therefore, the purpose of this study was to determine the relationship between BMI and balance in adolescent athletes during their developmental period. This study comprehensively examines the relationship between dynamic balance and BMI, which are among the basic injury risks, by gender and sport. Our primary hypothesis was that there is a relationship between BMI and balance in adolescent athletes. Other hypothesis was that BMI and balance would differ across gender and sports discipline.

Methods

Study Design

This cross-sectional study was approved by the Institutional Ethics Review Board of the authors' affiliated institutions ***(X).*** Prior to their participation, all athletes and their legal guardians provided written informed consent, and all procedures adhered to the principles outlined in the Declaration of Helsinki. A priori sample size calculation was performed using G Power 3.1.9.2, developed by Franz Faul at the University of Kiel, Germany. The sample size was calculated using the G*Power 3.1.2.1 program. A total of 86 patients were needed with a 5% significance level and 90% power and employing a medium effect size ($f^2 = 0.15$) [15].

Participant

A total of 311 athletes (mean age=15.29±4.75 years, mean BMI=20.31±3.28 kg/m^2) were included in the study. All athletes had been regularly participating in sports for at least 3 years and trained for at least 5 hours per week.

The inclusion criteria were being within the age between 10-17 years, to have been participating in regular sports for at least 3 years. The exclusion criteria were having a history of lower extremity surgery, neurological or systemic problems, conditions associated with congenital or developmental diseases, and congenital foot deformity.

Materials and Procedure

Sociodemographic variables (age and gender) and dominant side, sport branch, sport age, previous injuries and training frequency of the athletes were recorded. The current weight (kg) and height (cm) were measured by a single examiner **(X)**.

 doi:10.20944/preprints202602.0186.v1

Anthropometric Characteristics: To measure height, athletes stand in front of the measurement wall with their backs fully against it, feet shoulder-width apart and looking straight ahead. Height recorded in centimeters. For body weight assessment, the Tanita BC418MA (Tanita, Japan) device used [16]. This is a device which serves to estimate the components of body mass, based on the principles of bioelectrical impedance. Subjects had not eaten for at least 2 h before the measurement and had been asked to empty their bladders before the measurements began. Athletes asked to step barefoot onto the digital scale, look straight ahead, and hold the device's hand probes. Body weight recorded in kilograms. Body Mass Index (BMI) calculated by dividing total body weight by the square of height (weight (kg)/height (m^2)) (Canikli 2022). BMI recorded in kg/m^2. In the classification of BMI values, evaluations will be conducted using percentile tables or the Z-score (Standard Deviation-SD) table developed by the World Health Organization (WHO). Within this scope, assessments will be made using the WHO Anthro-Plus Program (Version 1.0.4) and the "WHO-2007 5-19 Years Growth Curves." This classification is based on WHO Growth Reference charts, which vary according to age and gender for children and adolescents [17].

Balance Assessment: Y-balance test, which is the most used balance assessment for athletes, was used. The Y-balance test used to measure the dynamic balance of athletes. They asked to stand at a marked point on a pre-drawn "Y" shape and reach with their toes in the anterior, posteromedial, and posterolateral directions. The test repeated three times for each direction, with both lower extremities and the average score recorded [18]. The Y-Balance Test is a reliable and valid tool for assessing dynamic balance in adolescent athletes, demonstrating good intra- and inter-rater reliability in this population [19,20].

Statistical Analysis

All statistical analysis conducted with IBM SPSS 22.0 (SPSS Incorporated Company, Illinois, ABD). Kolmogorov-Smirnov test and Q-Q plots were used to confirm the normality of the data distribution. Pearson's correlation coefficient was used to verify the association between the dependent measures and the independent measures. The Pearson's correlation coefficient was interpreted as (0 to 0.19 = none to slight; 0.20 to 0.39 = low; 0.40 to 0.69 = moderate; 0.70 to 0.89 = high; and 0.90 to -1 = very high) [21]. Linear regression was used to determine how much the change in BMI affected balance. ANOVA test and Student-t test were used to determine the difference between gender and sports branches. An alpha level of $p \leq 0.05$ was selected to indicate statistical significance.

Result

The demographic and clinical characteristics of the athletes are shown in Table 1. The BMI was associated with Y-balance test parameters on the dominant side of the athletes ($p<0.005$) (Table 2). A one unit change in BMI affected the anterior, posteromedial and posterolateral results of the Y-balance test by 12%, 2% and 4%, respectively. Girl athletes demonstrated better balance in the posteromedial ($p=0.001$) and posterolateral ($p=0.021$) directions, but poorer balance in the anterior direction ($p=0.029$) compared to boy athletes. Gender comparisons are given in Table 3. According to the results of ANOVA test, there was a difference between sports branches for balance and BMI parameters ($p=0.001$). Pairwise group comparisons of sports branches are given in Table 4.

Table 1. Demographic and clinical characteristics of the adolescent athletes.

Characteristics	Adolescent athletes (n=311)
Age (year)	15.29±4.75
Height (cm)	166.29±17.53

Weight (kg)	54.88±17.53
BMI (kg/m²)	20.31±3.28
Sports age (year)	5.10±3.32
Sport branch	n (%)
Volleyball	172 (55)
Basketball	40 (13)
Tennis	59 (19)
Orienteering	40 (13)
Injuries	n (%)
Upper extremity	9 (3)
Lower extremity	11 (4)

BMI: Body mass index.

Table 2. Relationship between body mass index and Y-balance test parameters.

		BMI (kg/m²)		
Y-balance Test Parameters	**Mean±SD**	**r**	**R^2**	**p**
Dominant side anterior (cm)	71.74±14.43	-0.348	0.121**	0.001*
Dominant side posteromedial (cm)	77.79±3.14	-0.149	0.022**	0.023*
Dominant side posterolateral (cm)	77.09±12.99	-0.220	0.048**	0.001*
Non-dominant side anterior (cm)	72.01±13.65	-0.405	0.160**	0.001*
Non-dominant side posteromedial (cm)	78.57±12.86	0.034	0.001	0.610
Non-dominant side posterolateral (cm)	77.78±12.98	0.097	0.009	0.140

BMI: Body mass index. *Pearson correlation test. **Linear regression analysis.

Table 3. Comparison of BMI and Y-balance parameters according to gender.

Parameters	**Female Athletes (n=147)**	**Male Athletes (n=164)**	**p**
BMI (kg/m²)	20.14±3.08	20.44±3.43	0.493
Dominant side anterior (cm)	69.82±13.43	73.41±15.09	0.029*

Dominant side posteromedial (cm)	82.53±12.12	73.67±12.63	0.001*
Dominant side posterolateral (cm)	78.92±11.40	75.50±14.07	0.021*
Non-dominant side anterior (cm)	70.18±11.67	73.61±15.03	0.028*
Non-dominant side posteromedial (cm)	82.46±11.86	75.18±12.77	0.001*
Non-dominant side posterolateral (cm)	80.51±11.74	75.41±13.56	0.001*

BMI: Body mass index. *Student-t test.

Table 4. Comparison of BMI and Y-balance parameters according to sport branch.

Parameters	Tennis (n=59)	Basketball (n=40)	Orienteering (n=40)	Volleyball (n=172)	p^1	p^2	p^3	p^4	p^5	p^6
BMI (kg/m²)	18.20±2.76	20.75±3.89	18.90±1.93	21.97±2.78	0.001*	0.175	0.001*	0.010*	0.044*	0.001*
Dominant side Anterior (cm)	52.38±6.94	76.97±12.20	79.03±12.42	75.45±1.43	0.001*	0.001*	0.001*	0.464	0.459	0.084
Dominant side Posteromedial (cm)	77.68±9.92	66.58±7.20	90.10±1.80	77.58±13.09	0.001*	0.001*	0.956	0.001*	0.001*	0.001*
Dominant side Posterolateral (cm)	70.69±11.28	66.15±17.67	90.43±9.57	78.72±9.27	0.126	0.001*	0.001*	0.001*	0.001*	0.001*
Non-dominant side Anterior (cm)	52.53±6.79	78.26±13.37	80.69±10.47	75.22±9.47	0.001*	0.001*	0.001*	0.373	0.098	0.002*
Non-dominant side Posteromedial (cm)	77.62±10.26	71.61±11.61	87.23±12.87	78.51±12.91	0.009*	0.001*	0.633	0.001*	0.002*	0.001*
Non-dominant side Posterolateral (cm)	71.97±12.48	63.41±11.56	92.77±9.52	79.61±9.33	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*

BMI: Body mass index. $p^{1:}$ Comparison of tennis and basketball players (Student-t test); $p^{2:}$ Comparison of tennis and orienteering players (Student-t test); $p^{3:}$ Comparison of tennis and volleyball players (Student-t test); $p^{4:}$ Comparison of basketball and orienteering players (Student-t test); $p^{5:}$ Comparison of basketball and volleyball players (Student-t test); $p^{6:}$ Comparison of orienteering and volleyball players (Student-t test).

Discussion

 doi:10.20944/preprints202602.0186.v1

The finding of study indicated that BMI is negatively correlated with balance in adolescent athletes, with higher BMI values adversely affecting balance. Increased BMI was found to have the most significant impact on anterior balance. When examining gender differences, it was found that girls had poorer anterior balance compared to boys, while their posteromedial and posterolateral balance was better than that of boys. When examining different sports disciplines (tennis, basketball, volleyball, orienteering), significant differences were observed in BMI and balance parameters among them.

Previous studies have demonstrated that excessive weight to have a detrimental effect on static and dynamic postural ability in adolescents [22-26]. D'Hondt et al. evaluated 60 adolescent and divided into 2 groups: normal weight and overweight [27]. They found that excessive BMI decreased medial-lateral and anterior-posterior stability. They revealed an initial difference in plantar skin sensation between BMI groups; overweight participants exhibited lower scores before and after the plantar desensitization protocol. Their study demonstrates that adolescent overweight and obesity have a negative impact on motor skill performance when postural balance is simultaneously challenged. McGraw et al. investigated postural balance in obese and non-obese prepubertal boys[28]. They stated that diminished dynamic stability, greater sway areas in medial/lateral direction in obese boys. In a systematic review examining the effect of age and overweight or obesity on foot sensitivity and postural control, they showed that overweight decreased plantar sensitivity and caused poor balance and postural stability [23]. Most studies showed that decreased foot sensitivity was related to worse balance and postural stability [23,29,30]. Overweight was associated with plantar sensitivity, with lower sensitivity and decreased postural stability observed in obese people. The findings of our study, in alignment with existing literature, indicate that overweight adolescent exhibit difficulties in the balance. Impaired stability in overweight adolescent may negatively impact their ability to participate in complex physical activities and sports. These balance related asymetries may lead limitations in physical activities and lead to sport injuries.

The Y-balance test is one of the most efficient tests to evaluate the dynamic limits of stability and asymmetry [31]. The success of the Y-balance test in predicting injuries has been examined in numerous studies [1,5,32]. Butler et al. conducted a study on American football players and found that 89.6% of those with a low Y-balance test score had an increased risk of non-contact lower extremity injury [33]. Individuals with anterior left/right asymmetries greater than 4 cm on the Y-balance test were 2.5 times more likely to sustain a lower extremity injury [34]. Haddad et al. reported that BMI on Y-balance test results were affected by 25% in their study in obese and non-obese high school students [35]. Similarly Stiffler et al. found an asymmetry in the anterior direction of the Star Excursion Balance Test to be predictive of lower extremity injury when controlling for sport, sex, and athletic position [36]. Plisky et al. found that male and female basketball players had more than 4 cm of asymmetry between limbs in the Y-balance test forward reach and showed that this was a predictor of lower extremity injuries [18]. Plinsky et al. conducted a systematic review and meta-analysis and reported that there is moderate to high-quality evidence showing that the Y-balance test is a reliable dynamic neuromuscular control test [37]. They emphasized that significant differences were observed between genders and sports disciplines. Therefore, the Y-balance test test is considered to be a useful and practical test for predicting injuries.

Several studies have shown that there may be a difference in balance between the gender [25,29,30]. Rusek et al. examined the relationship between fat mass and balance in adolescents in their study. They used a stabiliometer to evaluate balance [29]. They found that girls in adolescence have higher content of adipose tissue and balance parameters are better than boys. Kolic et al. investigated the effects of height, weight and gender on postural stability in 4-12 age group [30]. It was observed that balance skills improved with age and girls exhibited more mature balance strategies at an earlier age. Reduced BMI was associated with greater balance ability and postural control. The findings of this study suggest that increased BMI may be associated with poorer balance ability in children. Research has shown that gender differences in balance ability can be observed in children as young as 9 and 10 years old, with females demonstrating greater control over their center of gravity [38,39].

These results in the literature are similar to the present study. Considering the neuromuscular differences between boys and girls, girls develop a better integration between their vestibular, visual and proprioceptive systems and can react faster than boys with small muscle adjustments. As a result, they tend to have greater postural stability, indicative of more advanced balance development.

Previous studies have focused on the negative effect of obesity on the fundamental motor skills and performance of adolescents [25,27]. Specifically, severe deficits in fundamental movement skills, diagnosed as developmental coordination disorder, were significantly linked to a high percentage of body fat [40]. In certain sports such as ballet, dance, and gymnastics, good balance is important for optimal performance. Previous studies on body sway among athletes from different sports have shown that gymnasts have better postural stability than football players, swimmers and basketball players [22,29]. Diniz-Sousa et al. evaluated balance, body composition, knee maximal strength, aerobic capacity and physical activity in The Arkansas Active Kids Club [41]. They found that higher body mass, waist circumference and fat mass were associated with worse balance, while higher knee extension strength and peak oxygen uptake were associated with better balance. Additionally, they explained that fat mass percentage and waist circumference were the most important factors associated with balance performance. Czarnota et al. divided 240 participants aged between 14 and 17 years as swimmers, dancers, soccer players, archers and control group according to their sports and examined their balance [42]. They found that static balance was different according to the sport, archers were the athletes with the best balance, followed by swimmers. Trajkovic et al. examined postural balance in elite adolescent athletes into 7 different sports branches (basketball, dance, track and field, running, tennis, martial arts, speed skating) [43]. The athletes engaged in dance showed the highest postural control, compared with other sports. In the present study, according to the results of balance parameters, it was found that orienteering athletes had better balance in all 3 directions. The worst balance results were generally found to belong to tennis athletes. Orienteering is a sport that involves balance, strength, agility and coordination[44]. In studies, it has been found that the balance of orienteering athletes is better than runners and there is a relationship between the balance of orienteering athletes and muscle strength [44,45]. In a study comparing posturographic parameters between young taekwondo and tennis athletes, it was found that tennis players had worse balance similar to our study [46]. Considering the fact that the balance test was performed in a position different from the position in which specialization training is carried out, it can be assumed that the repetitive body position with disproportionate load on the lower limbs, ensuring better stability, may be remembered by the body and used in everyday life.

This study has several limitations. Our first limitation is that we did not record the fat percentage. Studies have shown that fat percentage is a determinant parameter on balance as well as BMI. Secondly, when we distribute the athletes according to branches, the number of volleyball players is relatively higher than the others. An additional limitation was that the injury history data was based on self-reports and was unclear. In future studies, injury history data entered using electronic medical records should be used to ensure the accuracy of the information. Future research should be conducted to identify additional risk factors for sports related injuries and the necessary components of effective injury prevention programs to reduce the risk of injury.

Conclusion

Our study provides evidence that balance parameters in adolescent athletes vary according to BMI, gender and sport branch. Adolescent athletes with higher BMI have been shown to have worse balance. It has been demonstrated that adolescent female athletes have better posteromedial and posterolateral balance than their male athletes. In addition, it was found that orienteering athletes had the best balance parameters among orienteering, volleyball, basketball and tennis sports. It is important to determine the determinants of balance in adolescent athletes in the developmental age to prevent future injuries.

Acknowledgments: Not applicable.

 doi:10.20944/preprints202602.0186.v1

Conflicts of Interest Statement: Not applicable.

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