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The effects of carrying extra weight on ankle stability in adolescent basketball players

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ABSTRACT

Purpose: The purpose of this study was to investigate the effects of weight on ankle stability in adolescent basketball players.

Methods: 20 non-injured subjects (age = 11.05 ± 1.5 years) were included in this study. Each subject performed a 15 min warm-up by running or riding a stationary bike. The Star Excursion Balance Test (SEBT), single-leg balance test (performed with eyes open and eyes closed) and vertical jump test were performed with dominant lower extremity. 1 week later, same tests were performed with a schoolbag. The schoolbag contained weight bars as 20% of the players own body weight.

Results: Only posteromedial component of SEBT had significant difference between non-weight measurement and weighted measurement ($p = 0.004$). Single-leg stance test performed with eyes open ($p = 0.006$) and closed ($p = 0.001$) had significant difference between non-weight measurement and weighted measurement. Also the vertical jump test had significant difference between non-weight measurement and weighted measurement ($p = 0.001$).

Conclusions: These findings indicate that 20% weight of their own body weight does not affect dynamic ankle stability and postural limitations, which are magnified by advancing weight. We are confident in our conclusions because of the three-way interaction noted with posterior/medial with weight in SEBT. Furthermore, Star Excursion Balance test is more effective both weight and non-weight in measuring functional stability of the ankle.

1. Introduction

Basketball is a demanding sport that requires participants to exhibit high levels of physical fitness and sport specific skills. It's well documented that ankle injuries occur frequently in basketball players causing them to miss extensive time from competition and place heavy demands on health care systems [1]. The ankle was found to be the second most common injured body site after the knee [2]. Lateral ligaments of the ankle are identified as the most commonly injured structures in athletes [3].

The essential elements of the neuromuscular control mechanism of the ankle joint are proprioception, balance and postural control [4]. Proprioception is the term used to describe a group of sensations including the sensation of movement and position of the joints and sensations related to the muscle force [5]. Proprioception is thought to play a more significant role than pain in preventing acute injury and the evaluation of chronic injury and degenerative joint disease [4,6]. Mechanoreceptors collectively offer feedback regarding joint pressure and tension, ultimately providing a sense of joint movement and position. Via afferent nerve fibers, this information is integrated with the visual and vestibular sensory systems into a complex control system that acts to control posture and coordination. Sensory information obtained from the somatosensory, visual and vestibular systems is interpreted in the central nervous system, and appropriate signals are relayed to the muscles of the trunk and extremities in order to maintain postural stability [7].

The ability to maintain the body's center of mass over the supportive foot is termed postural control [4]. Postural control has typically been assessed with variations of the Romberg test. Instrumented devices such as force plates have often been used to quantify postural control during variations of quiet standing [8].

Balance refers to the ability of a human to remain upright in stance [4]. Single-leg balance is studied by using force plate measure that quantifies postural stability, or the ability to limit large excursions of the center of pressure [8]. During single-leg stance, control of posture is accomplished through corrective movements, with some occurring through reflexive ankle muscle contractions [9]. There is some evidence to suggest that decreased static unipedal balance is a risk factor for ankle sprain reinjury in soccer [23]. In sports, an athlete is usually visually attentive to the game,

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(a) (b)

Fig. 1. Star Excursion Balance Test (a) without schoolbag, (b) with schoolbag.

and the activity is dynamic in nature at the time of injury. Therefore it is agreed that impaired dynamic unipedal balance may be more critical than static balance in sports [10].

The Star Excursion Balance Test (SEBT) is a series of 8 lower-extremity-reaching tasks reported to be useful in identifying lower extremity functional deficits [10,11,20]. Maintenance of balance during dynamic movements in performing the SEBT, involves the ability to keep the center of gravity over the stable base of support without losing one's balance [11]. Dynamic postural stability has been defined as the extent to which a person can lean or reach without moving the feet and still maintain balance. Olmsted et al. [12] believe that performance of the SEBT challenges the subject's limits of stability as he or she maximally reaches and is, thus, at least somewhat indicative of dynamic postural stability. They also found that when assessed with SEBT, subject with chronic ankle instability achieve significantly less reach distances when standing on their injured limb compared with their uninjured limb and when compared with uninjured subjects [12]. SEBT is shown to be a reliable and valid instrument for assessing dynamic postural control and balance [10–12]. Kinzey and Armstrong investigated the reliability of SEBT in four directions in subjects with ages ranging from 18 to 35 years and stated that SEBT is a reliable measurement for dynamic stability [11].

Many authors stated intrinsic and extrinsic risk factors for ankle injuries in athletes. Weight has been defined as an intrinsic risk factor for ankle sprains and overuse injuries [3,7,24]. Both load carriage and associated muscle fatigue have the potential to decrease a person's postural stability [13].

Numerous studies investigated the effect of weight only on posture but not on ankle stability or postural stability. The purpose of this study was to investigate the effects of weight to postural stability in adolescent basketball players.

2. Methods

Twenty adolescent basketball players voluntarily participated in this study. The study settled at Ankara University, School of Physical Education and Sports.

Inclusion criteria were:

1) playing basketball at least for 3 months;
2) free of cerebral concussions, vestibular disorders and lower extremity injuries for 3 months before the test;
3) no prior balance training.

Exclusion criteria were:

1) experiencing any major trauma like fractures or grade 3 ligament tears;
2) having had a surgical operation on the ankle joint.

An informed consent was taken from the parents' of the subjects. The University's Human Investigation Committee approved the study.

Age, body weight, height, dominant extremity, sports year, training hours per week and usage time of shoes was asked for each participant. Body Mass Index (BMI) was calculated by the following formula [21]. The subjects' height was measured to the nearest 0.1 cm without shoes. Subjects, wearing minimal clothing without shoes, were weighed to the nearest 0.1 kg. The body mass index was calculated as weight per squared height ($kg \times m^{-2}$) [21].

Each subject performed a 15 min warm-up by running or riding a stationary bike. Before all tests were performed, subjects were informed about the aim of this study and the test procedure by using verbal and visual demonstration. All tests were done in bare foot and the dominant leg as determined by the leg they used to kick the ball.

The SEBT is a functional test that consists of a single-leg stance on one leg with maximum reach of the opposite leg. A 2 m length, 7.5 cm wide adhesive tape was attached to the floor to eight different directions for the test. On the tape, every cm was written aiming an easy way to measure how far the subject reached. The SEBT was performed with the subjects standing at the center of the grid in which 8 directions (anterolateral-AL, anterior-A, anteromedial-AM, medial-M, posteromedial-PM, posterior-P, postereolateral-PL and lateral-L), extending at 45 degrees. Participants were let to practice the action for about a minute [11]. The test was started when the subject felt ready. The participants maintained single-leg stance with dominant leg, while they were reaching with the contralateral leg as far as possible to the directions (Fig. 1a). The subject then returned to bilateral stance while maintaining equilibrium. The average of 3 reaches for 8 directions were calculated. 5 s of rest time was given between reaches. All subjects started with AL direction and performed L, PL, P, PM, M, AM and A directions. Trials were discarded or repeated if the subject 1) did not maintain balance while reaching as fast as possible, 2) touched the line with the reached foot, 3) rotated the leg that was standing in the center of the grid [12].

Single-leg stance test was performed with eyes open and closed. During this test subjects tried to maintain their balance on their dominant leg as long as possible with contralateral knee bent and

(a) (b)

Fig. 2. Single-Leg Stance Test (a) without schoolbag, (b) with schoolbag.

not touching the weight bearing leg. The time for which the position was maintained was measured in seconds. The test was completed as soon as 1) the balance was failed; 2) 3 min time was performed [9] (Fig. 2a).

Vertical jump test was performed to provide general information about lower extremity strength. The participants jumped on their dominant leg. They stood by the side of a wall on which a tape showing the length was attached. The subjects raised their hand and the length was measured to determine participant's reference point. Than the participants jumped on their dominant legs and touched the tape on the wall as high as possible. Average of 3 reasonable jumps were calculated and subtracted from the reference point of each participant [22].

The participants performed all the tests a week later, with a schoolbag weighted 20% of the participant's body weight. The schoolbag contained weight bars as 20% of the players own body weight. Same procedure was performed (Figs. 1b and 2b).

Statistical analyses of comparing SEBT, one leg stance tests and vertical jump tests in adolescent basketball players with non-weight and weight factors were performed by using Wilcoxon test. The confidence interval was determined as 95%. The correlations between assessment parameters were analyzed with Spearman Correlation Coefficients, $r > 0.500$ was accepted as correlated [14]. The SPSS 15.0 statistical package program was used for data analysis.

3. Results

Twenty adolescent basketball players voluntarily participated (19 male 1 female; age = 11.05 ± 1.50 years) in this study. The descriptive information of adolescent basketball players are shown in Table 1.

Table 1
Descriptive information of adolescent basketball players.

	n	Min	Max	$X \pm SD$
Age (year)	20	9	14	11.05 ± 1.50
Body weight (kg)	20	26	88	45.82 ± 16.29
Body height (cm)	20	132	175	148.25 ± 11.73
Body mass index (kg/cm^2)	20	14.92	32.87	20.28 ± 4.35
Sports year (month)	20	1	72	29 ± 24.09
Training time (h/week)	20	2	17	4.73 ± 4.33
Usage time of shoes (month)	20	3	48	9.80 ± 10.42

No significant difference was found in the anterolateral (non-weight; min–max: 44.3–81, weight; min–max: 44–90; $p = 0.654$), anterior (non-weight; min–max: 50.6–85, weight; min–max: 45–91.33; $p = 0.332$), anteromedial (non-weight; min–max: 37–85, weight; min–max: 35–80; $p = 0.313$), medial (non-weight; min–max: 25–87, weight; min–max: 15.6–63.3; $p = 0.643$), posterior (non-weight; min–max: 37.3–83.3, weight; min–max: 29.3–90.6; $p = 0.073$), posterolateral (non-weight; min–max: 46.3–83.3, weight; min–max: 32–86.6; $p = 0.687$) and lateral (non-weight; min–max: 40–83.6, weight; min–max: 36.3–89.6; $p = 0.936$) directions of SEBT in adolescent basketball players. A significant difference was found only in posteromedial component of SEBT between non-weight and weight factors in adolescent basketball players (non-weight; min–max: 35.3–83.3, weight; min–max: 15.6–70.3; $p = 0.004$). The differences are shown in Table 2.

Significant difference was found between non-weight and weight factors for single-leg stance tests in both eyes open (non-weight; min–max: 8–180, weight; min–max: 2.91–134; $p = 0.006$) and eyes closed (non-weight; min–max: 2.02–20.87, weight; min–max: 1.09–7.3; $p = 0.001$) testing in adolescent basketball

Table 2
p-Values for star excursion balance tests between non-weight and weight factors.

SEBT						
Non-weight	Min–Max	$X \pm SD$	Weight	Min–Max	$X \pm SD$	p
Anterolateral	44.3–81	63.68 ± 10.53	Anterolateral	44–90	64.54 ± 10.05	0.654
Anterior	50.6–85	67.65 ± 9.24	Anterior	45–91.33	65.73 ± 10	0.332
Anteromedial	37–85	58.99 ± 13.32	Anteromedial	35–80	56.99 ± 11.37	0.313
Medial	25–87	49.51 ± 15	Medial	15.6–63.3	47.65 ± 11.31	0.643
Posteromedial	35.3–83.3	57.21 ± 14.35	Posteromedial	15.6–70.3	48.6 ± 11.15	0.004*
Posterior	37.3–83.3	60.12 ± 12.13	Posterior	29.3–90.6	55.46 ± 12.53	0.073
Posterolateral	46.3–83.3	60.25 ± 9.78	Posterolateral	32–86.6	59.69 ± 11.27	0.687
Lateral	40–83.6	60.2 ± 12.18	Lateral	36.3–89.6	60.8 ± 11.28	0.936

* $p < 0.05$.

Table 3
p-Values for single-leg stance test between non-weight and weight factors.

		Min–Max	$X \pm SD$	*p*
Eyes open	Non-weight	8–180	60.16 ± 48.24	0.006*
	Weight	2.91–134	30.19 ± 29.84	
Eyes closed	Non-weight	2.02–20.87	8.37 ± 4.98	0.001*
	Weight	1.09–7.3	3.6 ± 1.92	

* $p < 0.05$.

Table 4
p-Values for vertical jump test between non-weight and weight factors.

	Min–Max	$X \pm SD$	*p*
Non-weight	5.33–65.6	20.54 ± 14.51	0.001*
Weight	1.3–43.3	12.49 ± 9.59	

* $p < 0.05$.

players. Also a significant difference was found between non-weight and weight factors at vertical jump tests (non-weight; min–max: 5.33–65.6, weight; min–max: 1.3–43.3; $p = 0.001$) in adolescent basketball players. The differences are shown in Tables 3 and 4.

No relationship was found between BMI and sports year ($r = 0.172$), training time ($r = -0.169$), usage time of shoes ($r = 0.037$) and age ($r = 0.443$) parameters of adolescent basketball players. Also no relationship was found between sports year and training time ($r = 0.341$), usage time of shoes ($r = -0.240$) and age ($r = 0.176$); between training time and usage time of shoes ($r = 0.032$) and age ($r = -0.088$); between usage time of shoes and age ($r = 0.045$). The correlation coefficients and scatter plot graphs are shown in Table 5.

4. Discussion

We conducted this study to investigate the short-term effects of weight factor on postural stability in adolescent basketball players. Although the findings from this study did not denote a particular test technique as more beneficial, the findings support that 20% of body weight affects static ankle stability following the application of the test techniques for postural stability utilized in this study. When analyzing the 2 different methods either weighted or non-weighted, only immediate achievement in posteromedial components of SEBT is significant.

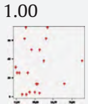
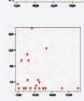
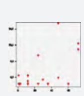
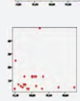
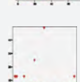
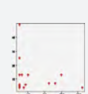
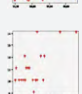
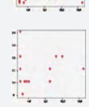
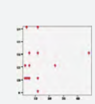
Chansirinukor et al. stated that the weight of the backpack has a negative effect on changes in cervical and shoulder posture, suggesting that carrying a backpack weighing 15% of body weight would be too heavy for high school students aged 13–16 years to maintain their normal postural alignment and standing posture [15]. Many authors have shown that children aged 11–13 years have an increased forward lean posture when carrying 17% of body weight, implying that such a weight may represent an overload for this age group of children. It is said that a student's bag should not exceed 10% of body weight. The amount of weight the students are able to carry and maintain their normal postural alignment is between 10% and 17% of the student's body weight [15]. According to these data we used a backpack weighing 20% of body weight for each adolescent in order to assess the effect of a backpack of 20% body weight on the ankle and overall stability.

Heller et al. investigated the effects of external weight carriage on postural stability in twenty-two female subjects (mean: 20.8 ± 1.7 years) and stated that there is a correlation between load carriage and stability. Standard measures of postural stability indicated that the subjects were less stable while carrying the backpack. Wearing an external load of 18.1 kg, which is less than the minimum load carried by military personnel, reduces postural stability in healthy, young females. This could translate into a higher likelihood of injuries such as ankle sprains in this population [13]. Ross et al. attributed impaired balance in individuals with lateral ankle sprains to damaged articular mechanoreceptors in lateral ankle ligaments, which resulted in proprioceptive deficits [8]. We measured static and dynamic ankle stability as it changes through external weight carriage and found that weight factor does not change through almost all parameters of SEBT (dynamic stability), but does change single-leg stance test or vertical jump test results (static stability). However, it must be noted that any changes observed may alter with adaptation over time.

Load carriage has been associated with spinal pain in both adolescents and adults, although it is not ethically possible to experimentally investigate the causal nature of this relationship [17]. Bloom et al. reported that carrying a backpack loaded 19 kg for men and 14 kg for women caused the subjects to lean forward; the bend was greatest above the hips but the knees and hips were also forward of the control position [19]. Seven et al. stated that back loading while sit to stand motion increased ankle dorsiflexion yielding a greater maximal dorsiflexion angle and more pronounced effects primarily in the ankle of healthy children [18]. All of these findings may affect ankle problems as a chain and cause ankle injuries.

Hertel et al. reported that the posteromedial component of the SEBT is highly representative of the performance of all 8 compo-

Table 5
Correlations between assessment parameters of adolescent basketball players.

r	BMI	Sports year	Training time	Usage time of shoes	Age
BMI	1.00	0.172	−0.169	0.037	0.443
Sports year		1.00	0.341	−0.240	0.176
Training time			1.00	0.032	−0.088
Usage time of shoes				1.00	0.045
Age					1.00

* $r > 0.500$.

nents of the test in limbs with and without chronic ankle instability. The anteromedial, medial, and posteromedial reach tasks may be used clinically to test for functional deficits related to chronic ankle instability in instead of testing all 8 tasks [20]. Subsequent to this, in our study we found a significant difference in posteromedial components of SEBT between non-weight and weight factors in adolescent basketball players.

The carrying, lifting and manipulating of heavy schoolbags may represent an overlooked daily physical stress for adolescents, and could lead to musculoskeletal symptoms in this population. At present, we do not know whether the adolescent students of today are going to expand the ranks of adult pain sufferers in the future. Therefore, if preventative measures can be introduced now with regard to safe load carriage in school students, it will not only help to protect young people while they are still developing, but will also ensure that the principles they learn now are carried through to the workplace as adults. A decrease in the incidence of ankle instability may result from an ergonomic approach to this working system including reducing the load carried by students, schoolbag redesign, curriculum planning and training. No single option will necessarily reduce the incidence of ankle instability but a combination is likely to help counter the overall risk of injury.

Chansirinukor et al. reported that there was a significant difference in the craniovertebral angle while carrying a backpack compared with the unloaded condition, after a five-minute walk. They also pointed out that the difference in the effect on posture between walking with a load for five minutes, and standing still with a load for five minutes was not tested and further research is needed to investigate the effects of backpack carriage in static and dynamic conditions on cervical and shoulder posture changes [15]. Starting from this point we searched the effects of load carriage on ankle stability. For this we used star excursion balance test, which took about 5 min, single-leg stance test and vertical jump test, which took about 3 min.

Beynnon et al. stated that gender does not appear to be a risk factor for suffering an ankle-ligament sprain [3]. Also Gribble et al. stated that males were found to have significantly greater excursion distances than females; however, after normalizing excursion distances to leg length, there were no significant differences related to gender [10]. We included both male and female adolescent basketball players to our study.

The findings support that a backpack including 20% of body weight does not affect dynamic ankle stability, but does affect static ankle stability for a significant period of time. Although the findings from this study did not denote a particular test technique as more beneficial, dynamic stability varied greatly based on protocol and method of analysis. However, with statistically significant main effects for each (e.g., protocol and analysis) in all directions (e.g., vertical, medial/lateral, and anterior/posterior), group main effects were potentially masked because the protocol and analysis scores were collapsed to determine group means. When analyzing the two different methods either weight or non-weight, only immediate gain in posteromedial components of SEBT was significant. According to published literature this test can be the best and proper for measuring ankle instability.

The limitation of our study was that any of the participants assessed did not follow up an exercise programme. Therefore the result of this study cannot be generalized for one measurement via functional performance tests. Long-term effects, which may explain the results by motor learning, may change the results.

Although ankle instability symptoms are believed to be multifactorial in origin, the carriage of heavy schoolbags is clearly a suspected contributory factor and may represent an overlooked daily physical stress for adolescents. Future work in adult athletes is required to confirm these results because long-term effects of posture and dynamic stabilization. In particular, longitudinal population studies on the risk factors for ankle instability symptoms in adolescents are needed.

5. Conclusion

Based upon the results of this investigation, we believe that when comparing weight factor in healthy ankles, vertical jump test and single-leg stance test will be more able to successfully detect differences in dynamic stability than a static stability. Therefore, the jump test should be used whenever possible, to better study the mechanisms of injury, as they would occur during athletic events. The most importantly, we are confident there would be a significant change in posteromedial reach weight factor during SEBT. Therefore, we recommend that researchers and clinicians utilize the functional tests for measuring ankle stability.

Conflict of interest statement

All authors have no conflicts of interest with respect to the data collected and procedures used within this study.

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