PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

The relationship of some factors affecting dynamic-static balance and proprioceptive sense in elite wrestlers*

Recep Aydin[1ABCDE], Gülfem Ersöz[2ADE], Ali Özkan[1ACD]

[1]Faculty of Sport Sciences, Bartin University, Turkey
[2]Faculty of Sport Sciences, Ankara University, Turkey

Authors' contributions: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Background and Study Aim The aim of this study is to identify and correlate some factors that are thought to affect the dynamic-static balance and proprioceptive senses of elite level wrestlers.

Material and Methods Descriptive statistics of a total of 13 volunteer elite freestyle wrestlers were determined after body weights, height, WAnT, active-squat jump tests, proprioceptive sense measurements, static and dynamic balance test measurements were taken. Then, the relationship test with the values obtained from static-dynamic balance and proprioceptive sense measurements, the Wingate anaerobic power test (WAnT) and vertical jump (active-squat) was examined.

Results As a result of Pearson Products Moment Relationship analyses, a significant relationship was found between static balance measurements and, WAnT anaerobic performance measurements, anaerobic performance measurements obtained from jumping, lower extremity isoinertial strength imbalance measurements ($p>0.05$). In addition, a significant relationship was found between dynamic balance measurements and WAnT anaerobic performance measurements ($p>0.05$). In addition, a significant relationship was found between proprioceptive joint angle deviation values and WAnT anaerobic performance measurements, anaerobic performance measurements obtained from jumping, and lower extremity isoinertial strength imbalance measurements ($p>0.05$).

Conclusions: In conclusion, as the findings of the study, the determining factors of the balance and angular error rates differ in the left and right legs of wrestlers. Especially, in order to minimize left leg balance and angular errors, training modules that increase proprioceptive performance should be applied to athletes.

Keywords: proprioception, dynamic balance, static balance, wrestling, male

Introduction

In order for the individual to maintain proper motor control, two different senses must work effectively. The sense of balance and vision in the inner ear constitute these senses. Preserving posture together with balance is not a passive fixation, but it is accepted as an active state that includes proprioceptive feedback processes [1]. As the ability to maintain the position, it regulates the proprioceptive sensory, vision and vestibular sensory organs, which provides the coordination between muscle contractions in the lower extremities in balancing the body and significantly affects all activities of daily life. In addition, the relationship between proprioceptive sense and sense of vision emerges as an important factor to control postural sway in static balance [2].

The proprioceptive system, which modulates muscle tone and activity, controls the load applied to bones, joints, tendons and ligaments. These loads are then converted into molecular signals by mechanosensors placed inside tissues. Thus, both growth and stability of the body are regulated [3]. According to some researchers, joint position sense is defined as a specialized model of tactile sense, which is defined in a wide range and includes neuromuscular control [4], while other scientists define proprioception as being aware of position or movement, that is, "afferent input". The afferent information required for fine tuning of motor control works fine on motor control, and this is provided by visual, vestibular and somatosensory receptors [5]. In addition, proprioception is examined in two subgroups as static and dynamic proprioception. While static proprioception means the conscious perception of the orientation of different extremities in the body with respect to one another; the speed and kinesthesia of the sense of movement is called dynamic proprioception. The knowledge of dynamic and static proprioception is attributed to the awareness of the angular movements in all joints applied in all planes and the ratios of the differences in these situations [6]. Kinesthesia, which includes the dynamic component of proprioception, defined as the sense of speed and joint motion, contains mechanoreceptors that give neromuscular abilities to athletes for each joint movement and joint sense [7]. Sensory receptors of proprioception in the skin, muscles, joints, ligaments and tendons continuous monitoring of changes in muscle length, joint angle changes of the other corresponding joint that implements the motion, and the forces generated during muscle contraction are of critical importance to the fulfilment of motor tasks. Proprioceptive sensory neurons (PSN) interpret and respond through spinal circuits. The paths to the brain encode this information and transmit it to the central nervous system [8, 9].

© Recep Aydin, Gülfem Ersöz, Ali Özkan, 2021
doi:10.15561/20755279.2021.0306

Proprioceptive mechanosensors are responsible for the continuous regulation of skeletal muscle length and tension to coordinate motor control [9]. Known and most important ones are specific sensory receptors known as muscle spindles (MS) and Golgi tendon organs (GTO), as axons that extend to the periphery from PSN cell bodies localized in the dorsal root ganglia (DRG) [10]. Among all mechanosensors, the two dominant types are considered as the muscle spindle and the Golgi tendon organ. These mechanosensors differ in morphology, location, measured input, effect and other properties [11-13]. Common to both mechanosensor is that they perceive the biomechanical environment and that special sensory afferent information quickly initiates a neural response in the fibers. As a result, muscle spindles and GTOs modulate local muscle tension, and have the ability to create reflex bridges [14].

Postural performance is defined as the ability to minimize postural sway [15]. In other words, it is accepted as an umbrella term that includes the act of maintaining, regaining or restoring a balance state during any postural balance or activity [16]. In addition to playing a role in sport-specific postural control, balance is also known to play a fundamental role in many athletic activities. Although the relationship between balance and performance is limited, it can contribute to high performance [17, 18]. Factors that change the responses of postural control are sensory information obtained from the somato sensory, visual, and vestibular systems. In addition, it includes motor responses that affect the quality and safety of performance during athletic performance, such as routine functional movements, coordination, range of motion (ROM), high intensity exercises [19] power values [20, 21] vertical protection of the center of mass (COM) of the body on the base of support (BOS) [17]. In order to have an optimal balance, three afferent information must be provided. These are proprioception, vision, and vestibular system [22].

Wrestling is one of the oldest competitive sports in the world as a high-intensity sport that requires regional power and whole-body power [23-26]. While athletes exhibit these skills on the mat, they apply many physical and affective characteristics such as strength, endurance, flexibility, balance, agility, strategy to the opponent during the match, in transforming the skill into points. As these characteristics are being exhibited, the skills enter into a systematic cycle, as successive and alike. During the match, this cycle is provided with conscious and unconscious feelings, awareness of movement, balance and postural control. This is reflected in the central nervous system as neural cumulative input and draws attention to the importance of proprioception in wrestling [27, 28].

Purpose: In this context, our study was conducted to determine the relationship between lower extremity strength imbalances and anaerobic performance, which are thought to affect the dynamic-static balance and proprioceptive senses obtained from elite level wrestlers.

Material and Methods

Participants

In the study, 13 national male athlete students (24.23 ± 2.01 years; 172.84 ± 8.08 cm; 80.67 ± 23.31 kg) who were educated at Bartın University Faculty of Sport Sciences and actively participated in wrestling training have participated voluntarily. The approval of Ankara University Faculty of Medicine Clinical Research Ethics Committee was obtained for the study to be implemented.

Research Design

In the research, there were athletes who competed as licensed athletes in wrestling for the last 5 years and participated in training at least 4 days a week. Athletes who competed in wrestling as freestyle athletes and represented Turkey in the A classification category participated. A randomized single-blind experimental study design with no control group was used in the study.

Anthropometric Measurement Tools

Height and body weight measurements were taken with scales integrated with SECA brand stadiometer. The precision of the device is ±0.01 mm and ±0.1 kg.

Anaerobic power and Capacity Measurement Tools

When determining anaerobic performance, Monark 894 branded Wingate Anaerobic Power Test (WAnT) was used. Participants were subjected to a 30-second test period by applying 75g of external resistance per body weight. In addition, as another method, squat jump and active jump tests were applied on the Lafayette-VertiMetric branded electronic jumpmeter.

Proprioception Measurement

For proprioceptive measurements, Baseline Digital Absolute+Axis 180˚ goniometer was used. In order to provide stability in the knee joint and to prevent any angular error, the digital goniometer is mounted on the Wicromed brand angle adjustable knee brace. Joint Position Sense (JPS) method, one of the proprioceptive measurement methods, was applied to the participants on double leg [29]. While determining the target angles, the knee joint positions during the skills used by the athletes in wrestling sport were examined and the close values, 90^o, 105^o, 120^o were determined as target angle.

Static and Dynamic Balance Measurement

Static and dynamic balance measurements were performed using Pro-Kin Tecnobody, PK200 branded device. Among the static balance data, the parameters of each participant's static balance scores were recorded. These parameters were determined as FBSD: back and forth sway, MLSD: left and right sway, ACOPY: pressure point to y-axis, ACOPX: pressure point to x-axis. The parameters among the dynamic balance data were determined as PL: total sway, AGP: mean sway velocity in the field, AP: mean degree of sway to the front and back, ML: mean degree of sway to the left and right. On the dynamic balance device, the balance scores of double leg with eyes open, dominant legs with eyes open and nondominant legs with eyes open were recorded.

Isometric Force Distribution Measurements

Isometric force distribution measurements were performed on the DESMOTEC D. device as the force values applied to double leg in the lower extremities and the percentage of imbalance in force. Isometric Durability test present in the system was used as a protocol. This protocol was applied to the participants for 30 seconds in professional mode. The participant has to pull the load cells (flywheel) upwards to generate the maximum possible force. The flywheel implements downward resistance on the participant by applying the same force. Power values on double leg during resistance and percentages of imbalance during load on double leg were separately recorded.

Statistical Analysis

As a result of the data obtained, first descriptive statistics data (standard deviation-mean) were taken from the SPSS 22.0 package program for the relationship level with dynamic-static balance and proprioceptive measurements. Then, the relationship level between the variables was examined with the Pearson Product Moment Relationship method in the SPSS 22.0 program.

Results

Of the wrestlers participating in the study; vertical jump, WAnT, isoinertial, proprioceptive sense values are shown in Table 1, while the mean and standard deviation values of static balance and dynamic balance values are shown in Table 2.

The relationship between static balance, dynamic balance and proprioceptive sense measurements, WAnT, vertical jump and imbalance values in isoinertial force were determined using Pearson's Product Moments Relationship analysis. The findings obtained as a result of the Pearson's Product Moments Relationship analysis;

The relationships between proprioceptive sense measurements and WAnT anaerobic performance values obtained from wrestlers are given in Table 3. No relationship was found between right leg knee joint proprioceptive joint angle error values and WAnT anaerobic performance values.

No relationship was found between static balance double leg with eyes open and double leg with eyes closed and WAnT anaerobic performance values (tabl.4).

There was no relationship found between the static balance measurements of the right leg with eyes open and double leg with eyes closed and the anaerobic performance values obtained from jumping (tabl.5). There was no relationship between the dynamic balance measurements of the wrestlers and the anaerobic performance values taken from jumping ($p > 0.05$). No relationship was found between right knee joint proprioceptive joint angle error values and anaerobic performance values obtained from jumping (tabl.6).

Table 1. Mean and standard deviation values of vertical jump, WAnT, isoinertial, proprioceptive sense values.

Measurements			n: 13
Vertivcal Jump	Squat Jump	AP (kg.m.s^{-1})	113,4202 ± 28,68
		RAP (watt.kg^{-1})	13,9968 ± 1,18
		AP (watt)	1134,2000 ± 286,85
	Active Jump	AP (kg.m.s^{-1})	120,7216 ± 31,76
		RAP (watt.kg^{-1})	14,8468 ± 0,93
		AP (watt)	1207,2162 ± 317,61
WAnT		IMP (watts)	943,78 ± 210,27
		RIM (watt / kg)	11,77 ± 1,85
		MP (watt)	775,49 ± 177,82
		RMP (watts / kg)	9,67 ± 1,62
		AP (watt)	617,08 ± 149,45
		RAP (watt / kg)	7,61 ± 0,69
Isoinertial (lower extremity)		Maximum force (kg)	279,93 ± 72,04
		Average force (kg)	161,57 ± 33,77
		Left leg imbalance (%)	24,00 ± 14,92
		Right leg imbalance (%)	3,0769 ± 2,06
Proprioceptive Sense	Right Leg	Knee joint 90° deviation error (°)	3,10 ± 2,96
		Knee joint 105° deviation error (°)	4,92 ± 3,08
		Knee joint 120° deviation error (°)	4,16 ± 3,30
	Left Leg	Knee joint 90° deviation error (°)	3,62 ± 2,74
		Knee joint 105° deviation error (°)	4,60 ± 2,72
		Knee joint 120° deviation error (°)	4,12 ± 3,00

AP: Anaerobic power RAP: Relative anaerobic power, IMP: Instantaneous maximum power, RIM: Relative instantaneous maximum power, MP: Maximum Power, RMP: Relative maximum power, AP: Average power; RAP: Relative average power

Table 2. Mean and standard deviation values of static balance and dynamic balance values.

Measurements			**n: 13**
Static Balance	Right Leg (eyes open)	FBSD (mm)	5,80 ± 1,27
		MLSD (mm)	7,73 ± 2,20
		ACOPY	11,64 ± 4,26
		ACOPX	-5,48 ± 12,87
	Left Leg (eyes open)	FBSD (mm)	5,61 ± 1,04
		MLSD (mm)	7,06 ± 1,80
		ACOPY	-6,66 ± 7,93
		ACOPX	-1,98 ± 13,90
	Double Leg (eyes open)	FBSD (mm)	2,94 ± 0,79
		MLSD (mm)	6,25 ± 2,23
		ACOPY	-10,42 ± 23,87
		ACOPX	-2,21 ± 4,65
	Double Leg (eyes closed)	FBSD (mm)	3,71 ± 1,66
		MLSD (mm)	5,86 ± 2,07
		ACOPY	-5,97 ± 20,91
		ACOPX	-3,09 ± 6,20
Dynamic Balance	Double Leg (eyes open)	PL (°)	345,7646 ± 78,06
		AGP °/sn	11,5254 ± 2,59
		AP (°)	-0,0762 ± 0,84
		ML (°)	-0,3223 ± 0,99
	Right leg (Eyes open)	PL (°)	511,5677 ± 93,85
		AGP °/sn	17,0515 ± 3,12
		AP (°)	-0,2323 ± 0,81
		ML (°)	0,7623 ± 0,89
	Left leg (Eyes open)	PL (°)	578,1231 ± 95,24
		AGP °/sn	19,2692 ± 3,17
		AP (°)	-0,5415 ± 1,08
		ML (°)	-1,8185 ± 1,04

FBSD: Forward-backward standard deviation, MLSD: Right-left standard deviation, ACOPY: Pressure applied to the Y-axis (average), ACOPX: Pressure applied to the X-axis (average), PL: Perimeter length, AGP: Average sway speed, AP: average degree of sway back to front, ML: average degree of sway left-right

Table 3. The relationship between proprioceptive joint angle deviation values and WAnT anaerobic performance values of the participants

				AP	**RAP**			**AC**	**RAP**
Measurements		**n:13**		**MAP (watt)**	**RMAP (watt/kg)**	**IMP (watt)**	**RIMP (watt/kg)**	**AAP (watt)**	**AAP (watt/ kg)**
Proprioceptive Sense	Left Knee Joint	90 (°)	r	,413	-,278	,477	-,245	,581	-,127
			p	,161	,357	,099	,420	,037*	,678
		105 (°)	r	,091	-,297	,223	-,170	,314	-,047
			p	,767	,324	,464	,578	,296	,880
		120 (°)	r	,310	-,323	,459	-,187	,511	-,228
			p	,302	,282	,115	,542	,075	,453

p>0.05; AP: Anaerobic power, RAP: Relative anaerobic power, AC: Anaerobic capacity, MAP (watt): 0-5sec maximum average power, RMAP (watt / kg): 0-5sec maximum average power per kg, IMP (watt): instantaneous maximum power, RIMP (watts / kg): instantaneous maximum power per kg, MV (watts): all test average power, OG (watts / kg): all test average power per kg.

Table 4. The relationship between static balance and dynamic balance measurements and WAnT anaerobic performance values of the participants

Measurements				**AP**	**RAP**			**AC**	**RAP**
n:13				**MAP (watt)**	**RMAP (watt/kg)**	**IMP (watt)**	**RIMP (watt/kg)**	**AAP (watt)**	**AAP (watt/kg)**
Static Balance	Right leg (Eyes open)	FBSD (mm)	r	,528	-,108	,539	-,109	,516	-,163
			p	,064	,725	,057	,724	,071	,596
		MLSD (mm)	r	,100	-,141	,155	-,108	,269	,127
			p	,745	,646	,612	,726	,375	,680
		ACOPY	r	,191	,161	,124	,108	,030	,035
			p	,532	,599	,685	,727	,923	,911
		ACOPX	r	,290	,175	,227	,084	,244	,294
			p	,337	,567	,457	,784	,421	,329
	Left leg (Eyes open)	FBSD (mm)	r	,440	,289	,444	,285	,373	,347
			p	,132	,339	,129	,345	,209	,246
		MLSD (mm)	r	,445	-,161	,446	-,242	,607	-,018
			p	,127	,600	,127	,425	,028*	,953
		ACOPY	r	,023	-,030	,129	,128	,062	,076
			p	,940	,922	,674	,678	,840	,804
		ACOPX	r	,089	,381	,015	,317	-,105	,345
			p	,772	,199	,960	,292	,734	,248
Dynamic Balance	Double Legs (Eyes Open)	PL (°)	r	,444	,629	,391	,540	,199	,473
			p	,128	,021*	,187	,057	,515	,103
		AGP °/sn	r	,445	,630	,391	,540	,199	,473
			p	,127	,021*	,186	,057	,514	,102
		AP (°)	r	-,135	,371	-,229	,257	-,302	,289
			p	,660	,212	,452	,397	,317	,338
		ML (°)	r	,345	,101	,360	,080	,271	-,076
			p	,249	,742	,227	,796	,370	,805
	Right Leg (Eyes Open)	PL (°)	r	,285	,567	,073	,278	,008	,352
			p	,345	,043*	,813	,358	,979	,238
		AGP °/sn	r	,286	,568	,073	,278	,009	,353
			p	,344	,042*	,812	,358	,978	,237
		AP (°)	r	,007	-,273	,031	-,294	,111	-,306
			p	,983	,368	,919	,329	,718	,309
		ML (°)	r	,341	,310	,195	,121	,198	,308
			p	,254	,302	,524	,694	,517	,306
	Left Leg (Eyes Open)	PL (°)	r	,271	,600	,185	,517	-,008	,446
			p	,371	,030*	,544	,070	,980	,127
		AGP °/sn	r	,270	,600	,185	,517	-,008	,445
			p	,371	,030*	,545	,070	,980	,127
		AP (°)	r	-,324	-,012	-,342	-,031	-,342	-,101
			p	,280	,969	,253	,920	,252	,743
		ML (°)	r	-,077	,069	-,273	-,195	-,239	-,264
			p	,804	,822	,367	,523	,431	,384

p>0.05; AP: Anaerobic power, RAP: Relative anaerobic power, AC: Anaerobic capacity, MAP (watt): 0-5sec maximum average power, RMAP (watt / kg): 0-5sec maximum average power per kg, IMP (watt): instantaneous maximum power, RIMP (watts / kg): instantaneous maximum power per kg, MV (watts): all test average power, OG (watts / kg): all test average power per kg.

Table 5. The relationships between static balance - proprioceptive sense measurements and anaerobic performance values obtained from vertical jumping of the participants

Measurements		n:13		SJAP (kg.m.s-1)	SJRAP (watt.kg-1)	SJAP (watt)	AJAP (kg.m.s-1)	AJRAP (watt.kg-1)	AJAP (watt)
Static Balance	Left leg (Ees open)	FBSD (mm)	r	,352	,289	,352	,316	,287	,316
			p	,237	,339	,237	,293	,341	,293
		MLSD (mm)	r	,619	,113	,619	,568	-,042	,568
			p	,024*	,713	,024*	,043*	,891	,043*
		ACOPY	r	,101	,268	,101	,062	,159	,062
			p	,743	,377	,743	,841	,604	,841
		ACOPX	r	-,113	,329	-,113	-,105	,506	-,105
			p	,714	,272	,714	,732	,078	,732
	Double legs (Eyes open)	FBSD (mm)	r	-,337	-,166	-,337	-,368	-,456	-,368
			p	,260	,587	,260	,216	,118	,216
		MLSD (mm)	r	,000	-,575	,000	,077	-,499	,077
			p	,999	,040*	,999	,802	,083	,802
		ACOPY	r	,213	-,210	,213	,221	-,312	,221
			p	,485	,491	,485	,468	,299	,468
		ACOPX	r	,101	-,343	,101	,150	-,277	,150
			p	,742	,251	,742	,624	,359	,624
Proprioceptive Sense	Left Knee Joint	90 (°)	r	,580	-,052	,580	,554	-,177	,554
			p	,038*	,867	,038*	,049*	,562	,049*
		105 (°)	r	,188	-,431	,188	,259	-,289	,259
			p	,538	,142	,538	,393	,338	,393
		120 (°)	r	,507	-,171	,507	,535	-,128	,535
			p	,077	,578	,077	,060	,677	,060
		90 (°)	r	,580	-,052	,580	,554	-,177	,554
			p	,038*	,867	,038*	,049*	,562	,049*

p>0.05; SJAP: squat jump anaerobic power, SJRAP: squat jump relative anaerobic power, AJAP: active jump anaerobic power, AJRAG: active jump relative anaerobic power

Table 6. The relationships between the static balance – proprioceptive sense and isoinertial lower extremity imbalance measurements of the participants.

Measurements		n:13		MF (kg)	AF (kg)	LLIP (%)	RLIP (%)
Static Balance	Right leg (Eyes open)	FBSD (mm)	r	,391	,455	-	,127
			p	,187	,118	-	,679
		MLSD (mm)	r	,088	,282	-	,173
			p	,775	,350	-	,572
		ACOPY	r	,340	,189	-	-,264
			p	,256	,537	-	,384
		ACOPX	r	,470	,533	-	,618
			p	,105	,060	-	,024*
	Left leg (Eyes open)	FBSD (mm)	r	,343	,275	-,038	-
			p	,252	,363	,901	-
		MLSD (mm)	r	,030	,306	,178	-
			p	,923	,310	,560	-
		ACOPY	r	,249	,111	,629	-
			p	,412	,718	,021*	-
		ACOPX	r	,407	,326	-,091	-
			p	,168	,277	,769	-
Proprioceptive Sense	Right Knee Joint	90 (°)	r	-,225	-,333	-	,035
			p	,461	,266	-	,909
		105 (°)	r	,174	,084	-	,166
			p	,569	,785	-	,587
		120 (°)	r	,424	,331	-	,409
			p	,149	,269	-	,166
	Left Knee Joint	90 (°)	r	,367	,480	,240	-
			p	,217	,097	,430	-
		105 (°)	r	,172	,320	,080	-
			p	,575	,286	,795	-
		120 (°)	r	,061	,148	,637	-
			p	,843	,630	,019*	-

p>0.05; MF: maximum force, AF: average force, LLIP: Left leg imbalance percentage, RLIP: Right leg imbalance percentage.

No relationship was found between static balance with double leg with eyes open and double leg with eyes closed and lower extremity isoinertial force imbalance measurements. No relationship was found between wrestlers' dynamic balance and lower extremity isoinertial force imbalance measurements.

No relationship was found between right knee joint proprioceptive joint angle error values and lower extremity isoinertial force imbalance measurements.

Discussion

According to the findings obtained, it is seen that the mean values of the wrestlers participating in the study have normal values are similar to the literature [30-32].

In static balance, statistically better results were obtained from the means, in favor of the balance measurements with eyes open, between the balance measurements with double leg with eyes open, and the balance measurements with double leg with the eyes closed (Table 2). The degree of sway of the left leg in static balance suggests that this may be related to the mass and volume of the muscles in the thigh and their inter-synergy. When dynamic balance measurements are considered, right leg dynamic balance measurements show statistically more positive results than left leg dynamic balance measurements. Double leg dynamic balance measurements show better scores than both single leg balance measurements (Table 2).

Isoinertial balance parameter distributions were examined on the condition of generating eccentric force after an equal amount of concentric force by means of a flywheel system. While athletes applied maximum force (279.93 ± 72.04kg) and applied average force (161.57 ± 33.77kg), their left leg imbalance percentages were determined as 24.00 ± 14.92%, and right leg imbalance percentages were determined as 3.07 ± 2.06%. As can be understood here, the force on both knee joints exhibits a great imbalance in the percentage force distribution in the left leg. Besides, the test yielded results that prove that the dominant leg is the right leg with percentages of imbalance in force (Table 1). As in the studies on the balance values of wrestlers with auditory special needs [33, 34] in the literature, the results of the studies with the participation of normal wrestlers [35, 36] are similar to the findings of this study. As the "sway" states in the balance parameters move away from the zero (0) point, it leads the athlete to imbalance. So much so that this situation is seen as determinant in both static and dynamic balance. However, it is seen that the anthropometric values of the athletes affect the balance scores [37], and it is also seen that balance studies in different branches are stimulated through different proprioceptive channels [38, 17]. In addition, it has been found that in the balance parameters applied on different surfaces, defense sports such as taekwondo have more single leg sways [39]. This situation is similarly observed in studies conducted in different branches [40]. Contrary to all these results, there are also studies in the literature stating that anthropometric properties may not be considered as descriptive in balance tests and additional research may be required for this [41].

The ability of individuals to do a work for balance performance is not only based on muscle strength, aerobic capacity, but may also be related to the explosive power generation of leg extensors [42-44] hamstring/quadriceps ratio. In case of imbalance, the most important risk factors are muscle strength applied to the knee joint, hip extensors-flexors, and lateral postural balance situation [45,46]. When the anaerobic results are examined at the level of means (Table 1), it is in line with the literature when considering the athletes of being at national level and at the level of training [47-49]. In some studies, it is seen that it has lower maximum, minimum and mean power values than our study in terms of training status and age criteria [50]. In the study examining the anaerobic performance values of different style wrestlers, it is seen that in the wingate lower extremity anaerobic performance test, Greco-Roman style has higher values than freestyle in all variables [51]. There are similarities between the anaerobic performance values of freestyle and Greco-Roman style athletes and the values of the athletes in our study, except for the maximum anaerobic power and fatigue index values.

High number of muscles, muscle mass and muscle fibers that make up the leg area indicate that the force generated by the muscle may be higher [52, 53]. In this respect, the fact that the dominant legs of the wrestling athletes in our group are right legs, and the other leg is lighter while maintaining balance on the mat may provide an advantage. Thus, less load will be placed on the body during balance, and athletes can be made to use their left leg as a limb to demonstrate their strategies.

On the other hand, deep ventilation resulting from anaerobic acidosis (lactic acid accumulation) caused by intense vigorous exercise also increases body release [54, 55]. It is known that affect postural control by causing proprioceptive stimulation, vestibular and visual inputs cause nerve muscle fatigue after vigorous exercise, central and affective weaknesses and cardio-respiratory changes [56-58].

In previous studies on the sense of joint position, traumas in the knee joint in general and the differences in the patient's return process were examined. Some of these studies included elderly individuals [59-61], young sedentary individuals [62], the relationship between the fall risks of elderly groups and pain syndromes [63-65], patients with knee osteoarthritis [66], the differences in the sense of joint position of the groups with and without athletes, and the position sense within the sports branches [67-69]. In our study, the smaller the angular error value and the closer to the taught degree (90^o-105^o-120^o) in proprioceptive measurements taken using the Joint Position Sense (JPS) method (Table 1), the better the awareness of the limbs. The better the awareness of the joint position, the more effective it will be in practicing the skill and positioning against the opponent in the match and turning this into points. Results showed that right leg values showed better results in 90 degree angular error than left leg 90 degree angular error. In 105 degrees and

120 degrees angular errors, it is seen that the angular error of the left leg is better than the angular errors of the right leg (Table 1). In this situation the posture of the wrestlers, the angular awareness of the support legs, their habits while applying the skill can cause angular errors. In addition, it is known that their weight values may be negatively correlated with the sense of position [70]. Obese individuals [71] and having a higher body mass index causes loss of joint stability and impaired proprioception [72]. However, attention has been drawn to the relationship between anaerobic exercise and muscle strength and proprioceptive sense [52], and it has been observed that the knee joint recovered within 30 minutes after the exercise and returned to its former sensory values at the end of 24 hours [73]. When we look at this acute effect, it is seen that as the anaerobic load increases, the proprioception senses are negatively affected [74]. In the results seen in our study, as the anaerobic capacity increases, the angular errors at 90 degrees increase, which supports this situation. So much so that besides strength training for muscle strengthening, proprioceptive specific exercises are seen as the most effective method to improve proprioceptive accuracy [75]. PNF (proprioceptive neuromuscular facilitation) method can be given as an example and widely used technique [76-78].

Conclusion

As a conclusion, the determining factors of the balance and angular error rates in the left leg and right leg of the wrestlers differ. Performance enhancing training modules should be applied on left leg balance and angular errors. These training modules should include methods that increase the effectiveness of proprioceptive receptors in muscles, tendons and joints.

Conflict of interest

The authors declare no conflict of interest.

References

1. İnal S. *Sports Biomechanics Basic Principles*. Ankara: Nobel Bookstore; 2004 (In Turkish).
2. Yong MS, Lee YS. Effect of ankle proprioceptive exercise on static and dynamic balance in normal adults. *Journal of Physical Therapy Science*, 2017; 29(2): 242– 244. https://doi.org/10.1589/jpts.29.242
3. Blecher R, Heinemann-Yerushalmi L, Assaraf E, Konstantin N, Chapman JR, Cope TC, et al. New functions for the proprioceptive system in skeletal biology. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 2018; 373(1759): 20170327. https://doi.org/10.1098/rstb.2017.0327
4. Lephart SM, Pincicivero DM, Rozzi SL. Proprioception of the ankle and knee. *Sports Medicine*, 1998; 25(3): 55– 149. https://doi.org/10.2165/00007256-199825030-00002
5. Ergen E, Ülkar B, Eraslan A. Review: Proprioception and Coordination. *Turkish Journal of Sports Medicine*, 2007; 42(2): 57–83 (In Turkish).
6. Guyton A, Hall JE, Çavuşoğlu H, Yeğen BÇ, Aydın Z. *Medical Physiology.* Nobel Bookstore; 2007. (In Turkish).
7. Rozzi S, Lephart SM, Fu FH. Effects of muscular fatigue on knee joint laxity and neuromuscular characteristics of male and female athletes. *Journal of Athletic Training*, 1999; 34(2): 106.
8. Pierrot-Deseilligny E, Burke D. *The Circuitry of the Human Spinal Cord: Its Role in Motor Control and Movement Disorders*. Cambridge: Cambridge University Press; 2005. https://doi.org/10.1017/CBO9780511545047
9. Windhorst U. Muscle Proprioceptive Feedback and Spinal Networks. *Brain Research Bulletin*. 2007; 73: 155–202. https://doi.org/10.1016/j.brainresbull.2007.03.010
10. Sonner MJ, Walters MC, Ladle DR. Analysis of Proprioceptive Sensory Innervation of the Mouse Soleus: A Whole-Mount Muscle Approach. *PLoS ONE*, 2017;12:e0170751. https://doi.org/10.1371/journal.pone.0170751.
11. Granit R. The functional role of the muscle spindles-facts and hypotheses. *Brain: a journal of neurology*, 1975; 98(4): 531–556. https://doi.org/10.1093/brain/98.4.531
12. Maier A. Development and regeneration of muscle spindles in mammals and birds. *Int. J. Dev. Biol*, 1997; 41: 1–17.
13. Moore JC. The Golgi tendon organ: a review and update. *American Journal of Occupational Therapy*, 1984; 38(4), 227–236. https://doi.org/10.5014/ajot.38.4.227
14. Proske U, Gandevia SS. The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiological Reviews*, 2012; 92(4): 1651–1697. https://doi.org/10.1152/physrev.00048.2011
15. Paillard T, Costes-Salon C, Lafont C, Dupui P. Are there differences in postural regulation according to the level of competition in judoists? *Br J Sports Med*, 2002; 36: 304–5. https://doi.org/10.1136/bjsm.36.4.304
16. Pallock A, Durward B, Rowe P, Paul J. What is balance? *Clinical Rehabilitation*, 2000; 14(4): 402–406. https://doi.org/10.1191/0269215500cr342oa
17. Hrysomallis C. Balance abilities and athletic performances. *Sports Medicine*, 2011; 41: 221– 232. https://doi.org/10.2165/11538560-000000000-00000
18. Alderton AK, Morıtz U, Moe-Nılssen R. Force plate and accelerometer measures for evaluating the effect of muscle fatigue on postural control during one legged stance. *Physiother Res Int*, 2003; 8: 187–199. https://doi.org/10.1002/pri.289
19. Erkmen N, Suveren S, Göktepe AS. Effects of Exercise Continued Until Anaerobic Threshold on Balance Performance in Male Basketball Players. *J Hum Kinet*, 2012; 33: 73–79. https://doi.org/10.2478/v10078-012-0046-0
20. Grigg P. Peripheral neural mechanisms in proprioception. *Sport Rehab*, 1994; 3: 2–17. https://doi.org/10.1123/jsr.3.1.2
21. Palmieri RM, Ingersoll CD, Stone MB, Krause BA. Center-of-.pressure parameters used in the assessment of postural control. *Journal of Sports and Rehabilitation*, 2002; 11: 51–66. https://doi.org/10.1123/jsr.11.1.51
22. Hammamı R, Behm DG, Chtara M, Othman AB, Chaouachı A. Comparison of static balance and the role of vision in elite athletes. *Journal of Human Kinetics*, 2014; 41(1): 33–41. https://doi.org/10.2478/hukin-2014-0030
23. Zaccagnı L. Anthropometric characteristics and body composition of Italian national wrestlers. *European Journal of Sport Science*, 2012; 12(2): 145–151. https://doi.org/10.1080/17461391.2010.545838

24. Lopez-Gullon JM. Physical fitness differences between freestyle and Greco-Roman elite wrestlers. *Arch. Budo*, 2011; 7: 217–225.
25. Vardar SA. The relationship between body composition and anaerobic performance of elite young wrestlers. *J. Sports Sci. Med*. 2007; 6: 34–38.
26. Mcguıgan MR, Wınchester JB, Erıckson T. The importance of isometric maximum strength in college wrestlers. *J. Sports Sci. Med.* 2006; 5: 108–113.
27. Hıemstra LA, Lo IK, Fowler PJ. Effect of fatigue on knee proprioception: implications for dynamic stabilization. *J Orthop Sports Phys Ther,* 2001; 31: 598–605. https://doi.org/10.2519/jospt.2001.31.10.598
28. Rıbeıro F, Olıveıra J. Aging effects on joint proprioception: the role of physical activity in proprioception preservation. *Eur Rev Aging Phys Act*, 2007; 4: 71–6. https://doi.org/10.1007/s11556-007-0026-x
29. Fortier S, Basset FA. The effects of exercise on limb proprioceptive signals. *Journal of electromyography and kinesiology*, 2012; 22(6): 795–802. https://doi.org/10.1016/j.jelekin.2012.04.001
30. Ramırez-Velez R, Argothyd R, Meneses-Echavez JF, Sanchez-Puccını MB, Lopez-Alban CA, Cohen DD. Anthropometric characteristics and physical performance of colombian elite male wrestlers. *Asian Journal of Sports Medicine*, 2014; 5(4). https://doi.org/10.5812/asjsm.23810
31. Mırzaeı B, Curby DG, Barbas I, Lotfı N. Anthropometric and physical fitness traits of four-time World Greco-Roman wrestling champion in relation to national norms: A case study. *Journal of Human Sport & Exercıse*, 2011; 6(2):406–413. https://doi.org/10.4100/jhse.2011.62.21
32. Koç H, Aydos L. Compare the Reaction Times of Turkish National Team Wrestlers. *European Journal of Physical Education and Sport Science*. 2018; 4(2).
33. Coşkun B, Unlu G, Golshaeı B, Koçak S, Kirazcı S. Comparison of the static and dynamic balance between normal-hearing and hearing-impaired wrestlers. *Montenegrin Journal of Sports Science and Medicine*, 2019; 8(1): 11–16. https://doi.org/10.26773/mjssm.190302
34. Alpay CB, Işık Ö. Comparison of body components and balance levels among hearing-impaired wrestlers and healthy wrestlers. *Acta Kinesiologica*, 2017; 11(1): 79–84.
35. Basar S, Duzgun I, Guzel Na, Cıcıoğlu I, Çelık B. Differences in strength, flexibility and stability in freestyle and Greco-Roman wrestlers. *Journal of Back and Musculoskeletal Rehabilitation*, 2014; 27(3): 321–330. https://doi.org/10.3233/BMR-130451
36. Polat SC, Cetın E, Yarım I, Bulgay C, Cıcıoglu HI. Effect of ballistic warm-up on isokinetic strength, balance, agility, flexibility and speed in elite freestyle wrestlers. *Sport Mont*, 2018; 16(3): 85–89. https://doi.org/10.26773/smj.181015
37. Çatal Ç. *Investigation of the relationship between anthropometric characteristics and balance performance in athletes in different branches*. Amasya: Amasya University Press; 2019. (In Turkish).
38. Perrın P, Devıterne D, Hugel F, Perrot C. Judo, better than dance, develops sensorimotors adaptabilities involved in balance control. *Gait & Posture*, 2002; 15: 187–194. https://doi.org/10.1016/S0966-6362(01)00149-7
39. Negahban H, Aryan N, Mazaheri M, Norasteh AA, Sanjari MA. Effect of expertise in shooting and Taekwondo on bipedal and unipedal postural control isolated or concurrent with a reaction-time task. *Gait & posture*, 2013; 38(2), 226–230. https://doi.org/10.1016/j.gaitpost.2012.11.016
40. Bahadoran R, Ghasemzadeh Y, Soleımanı T. Investıgatıng lower lımb strength and statıc balance ın elıte gymnasts and wrestlers wıth non-athletes. *30 International Conference on Biomechanics in Sports*, 2012; 276–279.
41. Moeın E, Movaseghı F. Relationship between some anthropometric indices with dynamic and static balance in sedentary female college students. *Turkish Journal of Sport and Exercise*, 2016; 18(1): 45–49. https://doi.org/10.15314/tjse.65406
42. Ilmarınen J. Job design for the aged with regard to decline in their maximal capacity: Part I–Guidelines for the practioner. *Int J Ind Ergon*, 1992; 10: 53–65. https://doi.org/10.1016/0169-8141(92)90048-5
43. Landers K, Hunter G, Wetzteın C, Bamman M, Weınsteır R. The interrelationship among muscle mass, strength and the ability to perform physical tasks of daily living in younger and older women. *J Gerontol Ser A Biol Sci Med Sci*, 2001; 56A(10): B443– B448. https://doi.org/10.1093/gerona/56.10.B443
44. Rantanen T. Muscle strength, disability and mortality. *Scand J Med Sci Sports*, 2003; 13: 3–8. https://doi.org/10.1034/j.1600-0838.2003.00298.x
45. Horak FB. Mechanistic and physiological aspects postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls. *Age Ageing*, 2006; 35(S2): 7–11. https://doi.org/10.1093/ageing/afl077
46. Orr R, Raymond J, Sıngh MF. Efficacy of progressive resistance training on balance performance in older adults: a systematic review of randomized controlled trials. *Sports Med*, 2008; 38(4): 317–343. https://doi.org/10.2165/00007256-200838040-00004
47. Gıerczuk D, Hübner-Woznıak E, Dlugolecka B. Influence of training on anaerobic power and capacity of upper and lower limbs in young greco-roman wrestlers. *Biology of Sport*, 2012; 29(3): 235. https://doi.org/10.5604/20831862.1003449
48. Farzad B, Gharakhanlou R, Agha-Alınejad H, Curby DG, Bayatı M, Bahramınejad M, Mäestu J. Physiological and performance changes from the addition of a sprint interval program to wrestling training. *The Journal of Strength & Conditioning Research*, 2011; 25(9): 2392–2399. https://doi.org/10.1519/JSC.0b013e3181fb4a33
49. Zorba E, Özkan A, Akyüz M, Harmancı H, Taş M, Şenel Ö. The relationship of leg volume and leg mass with anaerobic performance and knee strength in wrestlers. *Uluslararası İnsan Bilim Dergisi*, 2010; 7(1): 83–96. (In Turkish).
50. Saç A, Taşmektepligil MY. Evaluatıon of the results of three dıfferent anaerobıc power tests obtaıned by measurıng dıfferent sport groups. *Journal of Sports and Performance Researches*, 2011; 2(1): 5–12. (In Turkish).
51. Kılınç F, Özen, G. Comparison of Anaerobic Power Values and Heart Rate in Elite Freestyle and Greco-Roman Wrestlers. *Inonu University Journal of Physical Education and Sport Sciences*, 2015; 2(2): 21–34. (In Turkish).
52. Wang H, Jı Z, Jıang G, Lıu W, Jıao X. Relationship among proprioception, muscle strength, and balance. *Journal of Physical Therapy Science*, 2016; 28(12): 3468–3472. https://doi.org/10.1589/jpts.28.3468
53. Özkan, A, Sarol, H. Relatıonshıp Between Body Composıtıon, Leg Volume, Leg Mass, Anaerobıc Performance And Knee Strength In Clımbers]. *Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi*, 2008; 6(4), 175–181. (In Turkish). https://doi.org/10.1501/Sporm_0000000108
54. Hunter IW, Kearney RE. Respiratory components of human

postural sway. *Neuroscience Letters*, 1981; 25(2): 155–159. https://doi.org/10.1016/0304-3940(81)90324-4
55.Sakelları V, Bronsteın AM, Corna S, Hammon CA, Jones S, Wolsley CJ. The effects of hyperventilation on postural control mechanisms. *Brain*, 1997; 120(9): 1659–1673. https://doi.org/10.1093/brain/120.9.1659
56.Şimşek D, Ertan H. Postural kontrol ve spor: kassal yorgunluk ve postural kontrol ilişkisi. *Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi*, 2011; 9(4): 119–124. (In Turkish) . https://doi.org/10.1501/Sporm_0000000208
57.Schneıders AG, Sullıvan SJ, Handcock P, Gray A, Mccrory PR. Sports concussion assessment: the effect of exercise on dynamic and static balance. *Scandinavian Journal of Medicine & Science in Sports*, 2012; 22(1): 85–90. https://doi.org/10.1111/j.1600-0838.2010.01141.x
58.Bove M, Brunorı A, Cogo C, Faellı E, Ruggerı P. Effects of a fatiguing treadmill exercise on body balance. *Gait & Posture*, 2005; 21: 121. https://doi.org/10.1016/S0966-6362(05)80397-2
59.Granıto RN, Aveıro MC, Renno ACM, Oıshı J, Drıusso. Comparison of thoracic kyphosis degree, trunk muscle strength and joint position sense among healthy and osteoporotic elderly women: a cross-sectional preliminary study. *Archives of Gerontology and Geriatrics*, 2012; 54(2): e199–e202. https://doi.org/10.1016/j.archger.2011.05.012
60.Rıbeıro F, Mot J, Olıveıra J. Effect of exercise-induced fatigue on position sense of the knee in the elderly. *European Journal of Applied Physiology*, 2007; 99(4): 379–385. https://doi.org/10.1007/s00421-006-0357-8
61.Goble DJ, Coxon JP, Wenderoth N, Van Impe A, Swınnen SP. Proprioceptive sensibility in the elderly: degeneration, functional consequences and plastic-adaptive processes. *Neuroscience & Biobehavioral Reviews*, 2009; 33(3): 271–278. https://doi.org/10.1016/j.neubiorev.2008.08.012
62.Hosp S, Bottonı G, Heınrıch D, Kofler P, Hasler M, Nachbauer W. A pilot study of the effect of Kinesiology tape on knee proprioception after physical activity in healthy women. *Journal of Science and Medicine in Sport*, 2015; 18(6): 709–713. https://doi.org/10.1016/j.jsams.2014.09.004
63.Şekeröz S. *Effects of Chronıc Neck Paın on Balance, Joınt Posıtıon Sense, Head Posture and Flexor Muscle Endurance in Elderly*. Denizli: Pamukkale University Press; 2018. (In Turkish).
64.Topal Y. *Investigation of the Relationship Between Balance Parameters and Functional Performance and Joint Position Sense in Patients with Knee Osteoarthritis*. Ankara: Haccettepe University Press; 2018. (In Turkish).
65.Bayramlar K, Halıs S. Comparison of the joint position sense in transtibial amputees with and without phantom limb pain. *Fizyoterapi Rehabilitasyon*, 2008; 19(2): 85–91. (In Turkish).
66.Vıthoulka I, Beneka A, Mallıou P, Aggelousıs N, Karatsolıs K, Dıamantopoulos K. The effects of Kinesio-Taping® on quadriceps strength during isokinetic exercise in healthy non athlete women. *Isokinet Exerc Sci*, 2010; 18(1): 1–6. https://doi.org/10.3233/IES-2010-0352
67.Eıls E, Schröter R, Schröder M, Gerss J, Rosenbaum D. Multistation proprioceptive exercise program prevents ankle injuries in basketball. *Medicine & Science in Sports & Exercise*, 2010; 42(11): 2098–2105. https://doi.org/10.1249/MSS.0b013e3181e03667
68.Daneshjoo A, Mokhtar AH, Rahnama N, Yusof A. The effects of comprehensive warm-up programs on proprioception, static and dynamic balance on male soccer players. *PloS ONE*, 2012; 7(12): 51568. https://doi.org/10.1371/journal.pone.0051568
69.Arslan F, Erkmen N, Taşkın H, Sallı A, Ismet CG. Ankle joint position sense in male Taekwondo athletes after wobble board training. *Orıgınal Artıcle*, 2011; 197–201.
70.Moravvejı H, Ghanbarı A, Kamalı F. Proprioception of knee joint in atheletes and non atheletes obese. *Global J Health Sci*, 2017; 9: 286–293. https://doi.org/10.5539/gjhs.v9n2p286
71.Wang L, Lı JX, Xu DQ, Hong YL. Proprioception of ankle and knee joints in obese boys and nonobese boys. *Medical Science Monitor*, 2008; 14(3): 129–135.
72.Peltola EK, Lındahl J, Hıetaranta H, Koskınen SK. Knee dislocation in overweight patients. *American Journal of Roentgenology*, 2009; 192(1): 101–106. https://doi.org/10.2214/AJR.07.3593
73.Romero-Franco N, Martínez-López EJ, Hıta-Contreras F, Lomas-Vega R, Martínez-Amat A. Short-term effects of anaerobic lactic exercise on knee proprioception of track and field athletes. *Isokinetics and Exercise Science,* 2014; 22(3): 205–210. https://doi.org/10.3233/IES-140540
74.Göktepe M, Çakır E, Göktepe MM, Şenel Ö. Effect of maximal anaerobic loading on lower extremity proprioceptive sense in soccer players. *Journal of Education and Training Studies*, 2019; 7(2): 163–168. https://doi.org/10.11114/jets.v7i2.3768
75.Knoop J, Steultjens M, Van Der Leeden M, Van Der Esch M, Thorstensson C, Roorda L, et. al.. Proprioception in knee osteoarthritis: A narrative review. *Osteoarthritis and Cartilage*, 2011; 19(4): 381–388. https://doi.org/10.1016/j.joca.2011.01.003
76.Ganesh DP. *Effect of proprioceptive training on select motor fitness and skill performance variables of hockey players.* Indıa: Pondıcherry Unıversıty Press; 2012.
77.Sılva GCE, Sılveıra A, Novaes J, Dı Masıı F, Conceıção M, Dantas E. Acute effects of static and proprioceptive neuromuscular facilitation stretching on sprint performance in male swimmers. *Med Sport*, 2014; 67: 119–28.
78.Göktepe MM, Günay M. The effects of proprioceptive exercise programme given to female footballers their on balance, proprioceptive sense and functional performance. *Journal of Human Sciences*, 2019; 16(4), 1051–1070. https://doi.org/10.14687/jhs.v16i4.5824

*This entire article has been produced from the doctoral thesis *(Ankara University, Health Sciences Institute, TURKEY).*

Information about the authors:

Recep Aydın; (Corresponding author); https://orcid.org/0000-0001-8755-226X; g.recep.aydin@gmail.com; Bartin University; Bartın, Turkey.

Gülfem Ersöz; https://orcid.org/0000-0001-8813-3032; gersoztr@gmail.com; Ankara University; Ankara, Turkey.

Ali Özkan; https://orcid.org/0000-0002-2859-2824; ali_ozkan1@hotmail.com; Bartin University, Bartın, Turkey.

Cite this article as:
Aydin R, Ersöz G, Özkan A.The relationship of some factors affecting dynamic-static balance and proprioceptive sense in elite wrestlers. *Physical Education of Students*, 2021;25(3):178–188.
https://doi.org/10.15561/20755279.2021.0306

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited
http://creativecommons.org/licenses/by/4.0/deed.en

Received: 12.05.2021
Accepted: 19.06.2021; Published: 30.06.2021