Journal of Sport and Health Research 2020, 12(2):238-247

**García-Mayor, J.; Vegara-Ferri, JM. (2020).** Static Balance in Collegiate Volleyball Players: comparison of different unstable surfaces. *Journal of Sport and Health Research. 12*(2):238-247.

**Original**

# EQUILIBRIO ESTÁTICO EN JUGADORES DE VOLEIBOL UNIVERSITARIO: COMPARACIÓN DE DIFERENTES SUPERFICIES INESTABLES

# STATIC BALANCE IN COLLEGIATE VOLEYBALL PLAYERS: COMPARISON OF DIFFERENT UNESTABLE SURFACES

García-Mayor, J[1]; Vegara-Ferri, J.M[1].

[1]*Faculty of Sports Science. University of Murcia1*

Correspondence to:
**Jesús García Mayor**
Faculty of Sports Science. University of Murcia
C/ Argentina s/n, 30720, Spain
Tel. +34 665485383
Email: jesus.garcia9@um.es

*Edited by: D.A.A. Scientific Section Martos (Spain)*

editor@journalshr.com

Received: 18/06/2019
Accepted: 12/09/2019

Journal of Sport and Health Research 2020, 12(2):238-247

**RESUMEN**

**Objetivos.** El objetivo de este estudio fue comparar el equilibrio en diferentes superficies inestables utilizadas en rehabilitación y entrenamiento deportivo, así como estimar la diferencia entre la pierna dominante y no dominante en las diferentes superficies utilizadas. **Métodos.** 17 jugadores amateurs de voleibol de la Universidad de Murcia participaron voluntariamente en cuatro pruebas para medir el equilibrio estático y en las que se modificó la base de apoyo (sin plataforma, sobre disco de equilibrio, mesa de equilibrio y pelota Bosu). Los datos sobre la estabilidad del tronco se recogieron mediante un dispositivo inalámbrico que proporcionó datos sobre el coeficiente de variación. Para conocer la magnitud de las diferencias entre las diferentes superficies y entre la pierna dominante vs. no dominante, se calculó el valor del tamaño del efecto. Todos los datos fueron tratados con un nivel de significación de $p < 0{,}05$. **Resultados.** Los principales hallazgos muestran diferencias significativas ($p < 0{,}05$) en el coeficiente de variación entre las diferentes superficies, siendo la bola Bosu y la mesa de balance las plataformas más inestables (6,007 y 5,822, respectivamente). Parece haber un mayor promedio en el coeficiente de variación con respecto a la pierna dominante vs. no dominante en las tres plataformas utilizadas, aunque estas diferencias no son significativas ($p > 0{,}05$) en ninguna de las superficies. Además, la magnitud de las diferencias fue pequeña para el trabajo sin superficie, disco de balance y mesa de balance y mediana para la pelota Bosu. **Conclusiones.** Las jugadoras de voleibol aficionadas seleccionadas presentan algún desequilibrio bilateral; sin embargo, la magnitud de la diferencia parece ser relativamente pequeña e inconsistente.

**Palabras clave:** equilibrio; superficies inestables; control postural; asimetría; estabilidad.

**ABSTRACT**

**Objectives.** The study objective was to compare the balance on different unstable surfaces used in rehabilitation and sports training, as well as to estimate the difference between the dominant and non-dominant leg on the different surfaces used. **Methods.** 17 amateur volleyball players from the University of Murcia participated voluntarily in four tests to measure static balance and in which the support base was modified (without platform, on balance disc, balance table and Bosu ball). Data on trunk stability were collected by means of a wireless device that provided data on the coefficient of variation. In order to know the magnitude of the differences between the different surfaces and the dominant vs. non-dominant leg, the value of the effect size was calculated. All data were treated with a significance level of $p < 0.05$. **Results**. The main findings show significant differences ($p < 0.05$) in the coefficient of variation between the different surfaces, with the Bosu ball and the balance table being the most unstable platforms (6.007 and 5.822, respectively). There seems to be a higher average in the coefficient of variation with respect to the dominant vs. non-dominant leg in the three platforms used, although these differences are not significant ($p > 0.05$) in any of the surfaces. In addition, the magnitude of the differences was small for the work without surface, balance disk and balance table and medium for the Bosu ball. **Conclusions**. The selected amateur volleyball players present some bilateral imbalance; however, the magnitude of the difference seems to be relatively small and inconsistent.

**Keywords:** balance; unstable surfaces; postural control; asymmetry; stability.

Journal of Sport and Health Research 2020, 12(2):238-247

## 1. INTRODUCTION

Volleyball players often have imbalances in the pelvis and lower extremities that often occur during jumping actions and can lead to a shortening of the hip musculature and a knee injury (Sommer, 1988). In addition, the most frequent injury in this sport usually occurs in the ankle due mainly to sprains that occur in the actions of jumping near the net by sudden movements of the joint (Eerkes, 2012) and whose risk of injury by recurrence in 6 months is 42% (Bahr and Bahr, 1997). For this reason, stability training is essential to treat pathologies in this sport, related to trunk instability (Sharma, Geovinson, and Sandhu, 2012), improve jumping stability (Lesinski, Prieske, Demps, and Granacher, 2016) and reduce the risk of ankle injury (Cristofoli, Peres, Cecchini, Pacheco, and Pacheco, 2016; Verhagen et al., 2004).

In volleyball players it has been seen that there may be asymmetries due to the repetitive technical gestures made in this sport. To corroborate, there is often an asymmetry of the lower extremity extensors that is not clear if it could be due to a cause of the sport's techniques or an injury (Mattes, Wollesen, and Manzer, 2018). In addition, bilateral asymmetries have been documented in some of the areas most involved in this sport, as is the case of the shoulder for the action of the spike (Hadzic, Sattler, Veselko, Markovic, and Dervisevic, 2014). Asymmetries between the dominant and non-dominant leg have also been discussed above. In this way, a recent study carried out with basketball and volleyball players has observed asymmetries in the levels of force between the dominant and the non-dominant leg, with up to 10-15% asymmetry of force in the vertical jump (Fort-Vanmeerhaeghe, Gual, Romero-Rodriguez, and Unnitha, 2016). Despite this evidence, there are also contradictory studies. There is evidence from other recent studies that, despite having found lateral differences in the vertical jump, these differences have been of low magnitude and indifferent (Stephens, Lawson, and Reiser, 2005).

In spite of the previous studies mentioned, the research developed to know the capacity of balance and asymmetries between the dominant and non-dominant extremities of the volleyball players are limited in the international literature. However, some studies have been documented that analyse the balance capacity (Agostini, Chiaramello, Canavese, Bredariol, and Knaflitz, 2013; Hrysomallis, 2007; Pau, Loi, and Pezzotta, 2012). Agostini et al. (2013) attempted to analyze body roll during bipedal upright stance in volleyball athletes and healthy non-athlete controls and also examined the impact of the visual system on postural control. Pau et al. (2012), in young volleyball players, considered the effect of a training program with different positions (bipolar balance and monopodal balance) and compared the effects between volleyball players and a control group made up of healthy subjects. Differences in balance capacity between the dominant and non-dominant limbs in athletes and healthy subjects have also been documented above (Alhusaini et al., 2017; Brown, Brughelli, and Lenetsky, 2018; Hudson, Garrison, and Pollard, 2016; Promsri, Haid, and Federolf, 2018; Teixeira, de Oliveira, Romano, and Correa, 2011). Despite this, little is known about the differences in monopodal static balance that may exist between different unstable surfaces that are commonly used in rehabilitation and sports training programs, such as the balance disc, balance board and Bosu ball; and the differences between the dominant and non-dominant limb on each of these unstable platforms. So far there are studies carry carried out on athletes in different sports who have compared different situations of static balance. For example, in the literature there are studies that show that visual absence is a factor an important factor to modify the equilibrium (Hammami, Behm, Chtara, Othman, and Chaouachi, 2014). However, the evidence on the differences that may exist between the surfaces mentioned above is scarce.

Analysis of balance capacity and asymmetries between dominant and non-dominant leg is important because they are factors that can influence injury rates (Brophy, Silvers, Gonzales, and Mandelbaum, 2010; Hrysomallis, 2007; Ruedl et al., 2012). Moreover, it is recommended in the literature that sports training professionals use a variety of different exercises to improve balance, including exercises on increasingly challenging surfaces, in order to make decisions about tasks and sensory availability during evaluation and training (Hammami et al., 2014). In this context, knowing which training surfaces are more unstable and to what extent they can predict lateral asymmetries is essential to implement a training program that is progressive, suitable and effective in improving stability, thus being a program that adapts to the generalities and morphological and functional characteristics of athletes.

The purpose of this study is to compare monopodal static balance on different unstable surfaces in university amateur volleyball players, as well as to estimate the differences between the dominant and non-dominant extremities depending on the different surfaces used.

## 2. MATERIAL AND METHOD

Seventeen healthy, recreationally active adults, 11 men and 6 women amateur volleyball players from the University of Murcia (mean ± SD, 22.60± 2.18 years) voluntarily participated in this study. The participants gave their informed consent in writing to participate in this study. As inclusion and exclusion criteria, subjects who presented some type of acute pathology and, therefore, could not practice volleyball at the time of measurement were excluded from the study. In addition, all of them had to play university volleyball.

### 2.1 Measures

The wireless device WIMU PROTM (RealTrack Systems, Almeria, Spain) was used as a data collection instrument. This device monitors physical activity through different sensors (accelerometers, gyroscopes, magnetometer, GPS, UWB, among others), providing accurate and constant information through a flow of data in real time. The Qüiko software (RealTrack Systems, Almería, Spain) was used to calculate the coefficient of variation on the accelerometer signal. The sensor used in this investigation was the signal that is called total acceleration (AcelT) which is identified as the total acceleration recorded in the three orthogonal axes of the accelerometer (x, y, z). The AcelT measures the combination of gravity and changes in horizontal and vertical movements when the accelerometer is connected to a segment or object of the body (O'Donovan, Kamnik, O'Keeffe, and Lyons, 2007). The data were recorded at a sampling frequency of 1000 Hz.

### 2.2 Procedures

The evaluation process was carried out in the Polivante building of the Espinardo Campus of the University of Murcia. The test was completed throughout the same day. The subjects were instructed about the test to be performed and received information about the measuring instrument. In addition, all participants performed a general dynamic warm-up of the lower and upper extremities and a similar warm-up to that used in the training sessions, which includes balancing work on the different surfaces used. Specifically, the balancing work consisted of two 30-second series on each surface with each extremity with a 30-second rest between exercises. Finally, the subjects completed the assessment protocol. The static balance was evaluated on the four surfaces using this order: 1) without platform, 2) balance disc, 3) balance table, 4) Bosu ball. The order of completion of the 4 surfaces was randomized for all participants equally.

Before evaluation using the measuring device, the automatic start process and the synchronization of the data recording instrument were considered. The automatic start has been taken into account to eliminate the sources of error suffered by the accelerometers (Wang, Liu, Fan, and Ieee, 2006). Afterwards, the device was placed in the lumbar zone (center of masses) of the participating subjects, being fixed by means of an elastic band.

### 2.3 Protocol used for the assessment of trunk instability

Modification of the Frontal Plane Testing was used to measure the stability of the trunk (Weir et al., 2010). Subjects began standing on the dominant limb with the hip and knee in a neutral anatomical position. The trunk was upright, without rotation or lateral flexion, and the contralateral leg was positioned with the hip in a neutral position and the knee in a 90 degree flexion. After the test with this limb, the same action was performed with the non-dominant limb. This same protocol was used on the different surfaces used (without platform, balance disc, balance table and Bosu ball). For the change of support leg on unstable surfaces, the subjects rested on the ground for 5 seconds and then kept the other leg on the unstable surface. The end of the test was established at 20 seconds of duration or in the case that the subject separated any of the hands from their iliac crests or touched the ground with the limb in suspension. The dominant extremity of each subject was determined as the lower extremity on which the athlete puts most of his weight during the approach in the hitting phase, being the same side as the arm used to hit the ball (Hudson et al., 2016).

Journal of Sport and Health Research 2020, 12(2):238-247

**2.4 Statistics analysis**

Firstly, the values of the coefficient of variation were used to know the stability of the trunk of each extremity and in each of the surfaces used. Next, a descriptive analysis was carried out to know the mean and the standard deviation in the coefficient of variation of both the dominant and non-dominant leg in each of the surfaces used. The Shapiro-Wilk test was used to determine the normality of the variables. All variables reported a normal distribution. Therefore, the mean difference test (T Student for related samples) was carried out, comparing the coefficient of variation between each of the surfaces used and between the dominant and non-dominant leg. To know the magnitude of the differences found, the effect size (TE) was calculated using Cohen's d (1988) considering the values as small effect ($d < 0.2$), medium effect ($0.2 \leq d < 0.6$), high effect ($0.6 \leq d < 1.2$) and strong effect ($d > 1.2$). Statistical analyses were performed using the IBM SPSS Statistics 20.0 statistical package (IBM Corp., Armonk, NY, United States) and statistical significance was established at $p < 0.05$.

## 3. RESULTS

Table 1 shows the comparison in the coefficient of variation between the work without unstable surface and the different surfaces used considering the dominant and non-dominant leg. In addition, the mean between the dominant and non-dominant leg can also be observed. When considering the mean between the dominant and non-dominant leg, the results indicate a higher coefficient of variation in the Bosu ball platform (6.007) and the balance disc (5.822).

**Table 1.** Comparison of static balance between the different unstable surfaces used and balance without unstable surface, considering the coefficient of variation.

| | *Mean* | *SD* | *ES$^a$* | *ES$^b$* | *P* |
|---|---|---|---|---|---|
| **D** | | | | | |
| None | 1.238 | 0.296 | - | - | - |
| Balance disc | 5.929 | 2.795 | 3.04 | ST | <0.001 |
| Balance table | 3.75 | 1.233 | 2.07 | ST | <0.001 |
| Bosu Ball | 6.603 | 4.311 | 3.40 | ST | <0.001 |
| **ND** | | | | | |
| None | 1.285 | 0.377 | - | - | - |
| Balance disc | 5.715 | 3.421 | 2.33 | ST | <0.001 |
| Balance table | 3.5 | 1.763 | 2.07 | ST | <0.001 |
| Bosu Ball | 5.411 | 2.054 | 3.40 | ST | <0.001 |
| **D-ND** | | | | | |
| None | 1.261 | 0.334 | - | - | - |
| Balance disc | 5.822 | 3.078 | 2.67 | ST | <0.001 |
| Balance table | 3.625 | 1.503 | 1.78 | ST | <0.001 |
| Bosu Ball | 6.007 | 3.38 | 2.56 | ST | <0.001 |

D: dominant leg; DN: non-dominant leg; D-ND: mean of dominant and non-dominant leg. *ES$^a$:* effect size showing the difference between working on unstable surfaces and working without an unstable surface. *ES$^b$*: effect size [small effect ($d < 0.2$) = S; medium effect ($0.2 \leq d < 0.6$) = M; high effect ($0.6 \leq d < 1.2$) = H; strong effect ($d > 1.2$) = ST].

Figure 1 and 2 shows the cross-comparison between all the surfaces used as a function of the coefficient of variation. It should be noted that between the balance disc and Bosu ball there were no significant differences in both the dominant and non-dominant leg.

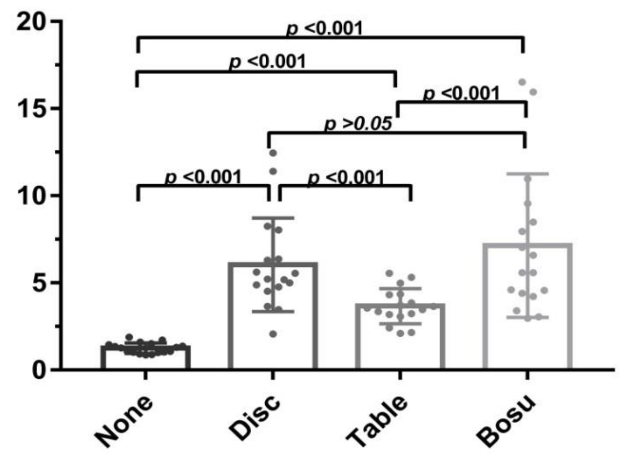


**Figure 1.** A cross-comparison of all surfaces used considering the coefficient of variation. The figure shows the average in the coefficient of variation considering the mean of the dominant and non-dominant leg.

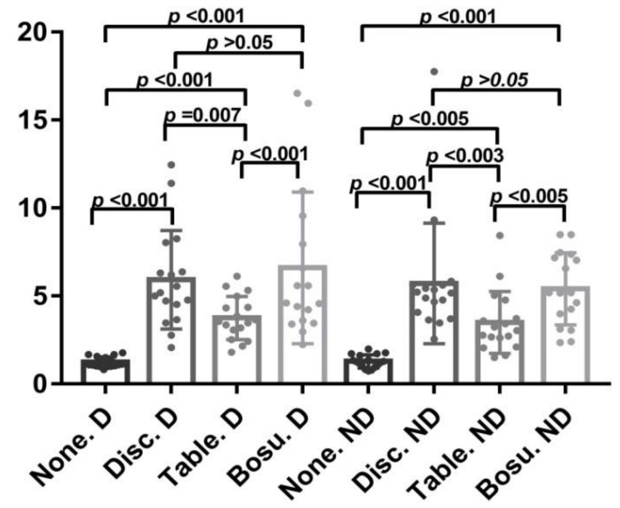

**Figure 2**. A cross-comparison of all surfaces used considering the coefficient of variation. The figure shows the differences in the average for each surface but independently considering the dominant (D) and non-dominant leg (ND).

Table 2 shows the differences between the dominant and non-dominant leg on each surface used. The results revealed that the coefficient of variation was relatively similar between dominant and non-dominant leg when measuring without instability platform (1.238 dominant leg vs 1.285 non-dominant leg, p>0.05). It should be noted that on the three unstable platforms the average coefficient of variation was lower for the strong leg vs. the skillful leg (5.929 vs. 5.715 in the balance disc, 3.75 vs. 3.5 for the table and 6.603 vs. 5.411 for Bosu). However, despite the differences found in the average coefficient of variation, the results were not significant for the different unstable platforms used (p >0.005).

**Table 2**. Coefficient of variation in each surfaces used, comparing the dominant and non-dominant leg.

| | | *Mean* | *DE* | *ES^a* | *ES^a* | *P* |
|---|---|---|---|---|---|---|
| **None** | **D** | 1.238 | 0.295 | 0.14 | S | =0.521 |
| | **ND** | 1.285 | 0.377 | | | |
| **Balance disc** | **D** | 5.929 | 2.795 | 0.07 | S | =0.783 |
| | **ND** | 5.795 | 3.421 | | | |
| **Balance table** | **D** | 3.75 | 1.233 | 0.17 | S | =0.49 |
| | **ND** | 3.5 | 1.763 | | | |
| **Bosu ball** | **D** | 6.603 | 4.311 | 0.37 | M | =0.161 |
| | **ND** | 5.411 | 2.054 | | | |

D: dominant leg; DN: non-dominant leg; $ES^a$: effect size showing the difference between working on unstable surfaces and working without an unstable surface. $ES^b$: effect size [small effect (d < 0.2) = S; medium effect (0.2 ≤ d < 0.6) = M; high effect (0.6 ≤ d < 1.2) = H; strong effect (d > 1.2) = ST].

## 4. DISCUSSION

The main findings showed significant differences between the different surfaces, with the Bosu ball and the balance table being the most unstable platforms. However, although a higher average coefficient of variation was observed with respect to the dominant vs. non-dominant leg, no significant differences were observed in the different platforms used.

Numerous previous studies have been published on the measurement of differences between dominant and non-dominant leg in athletes. To date, there has been a great deal of research that has attempted to analyse differences in speed, for example in kicking in football (Dorge, Andersen, Sorensen, and Simonsen, 2002; Masuda, Kikuhara, Demura, Katsuta, and Yamanaka, 2005), in muscle strength (Fort-Vanmeerhaeghe et al., 2016; Magalhaes, Oliveira, Ascensao, and Soares, 2004) and differences in knee stability (Dingenen, B., Malfait, B., Nijs, S., Peers, K. H., Vereecken, S., Verschueren, S. M., and Staes, F. F. (2015). There are also studies whose focus has been to know the differences in balance and postural control (Bressel, Yonker, Kras, and Heath, 2007; Varekova, Vareka, Janura, Svoboda, and Elfmark, 2011). However, to the point of our reach, this is the first study that has tried to investigate possible differences in the balance of amateur volleyball players between dominant and non-dominant leg using different unstable surfaces that are usually used in training and rehabilitation protocols. The most remarkable results of this study suggest that the differences observed in the different surfaces used are not significant between the dominant and non-dominant leg (p>0.05) despite a trend towards a higher coefficient of variation in the dominant leg compared to the non-dominant leg. Likewise, observing also the coefficient of variation, it stands out that the unstable platforms that generate more imbalances are Bosu ball (6.007) and the balance disc (5.822). It should be pointed out that the differences in Bosu ball between the dominant and non-dominant leg are the largest when compared with the rest of surfaces, with a medium effect size.

Previous studies have tried to analyze differences in the balance between the dominant and non-dominant leg. Thus, McCurdy and Langford (2006), attempted to determine the relationship between unilateral squat force and static balance measures in order to compare the performance of balance between the dominant and non-dominant leg in apparently healthy men and women. Their results did not show a significant correlation between strength and static balance and determined that performance in static balance between both legs could not be determined by leg dominance. Nevertheless, they concluded that similar studies were needed to compare the contralateral balance of the legs, mainly in the sports setting due to repetitive technical gestures that lead to asymmetries. Thus, in sportsmen and women, certain studies have been carried out to observe these differences. Akinoglu and Kocahan (2018) recently conducted a study to observe differences in balance between the dominant and non-dominant leg using a sample of 20 visually and hearing impaired athletes. As in the

Journal of Sport and Health Research 2020, 12(2):238-247

current study, they observed no differences in balance capacity between the dominant and non-dominant leg. On the other hand, Teixeira et al. (2011) observed the dynamic unipodal balance in football players. Their results revealed no differences in the balance between the dominant and non-dominant leg. Similarly, Gstottner et al. (2009), using a sample of amateur footballers, measured the differences in balance using the following instruments: Biodex Stability System and Tetrax System. As in the results found in the present study, the authors observed a trend toward greater imbalance in the dominant leg compared to the non-dominant leg, however, none of the tests performed in their study revealed statistically significant differences in the ability to balance between the two extremities. Certain studies have also emerged in volleyball. In this context, a recent study conducted with 90 women volleyball players examined the differences in stability between the dominant and non-dominant leg in the Lower Quarter Y-balance considering three positions: anterior, posteromedial and posterolateral (Hudson et al., 2016). The authors also found no significant differences between dominant and non-dominant leg scores.

Considering previous studies, uncertainty about which limb is defined as dominant or non-dominant should be considered as a discrepancy issue. A consensus has been suggested to define the term dominant leg, as well as the standardization of a test to find out the dominant side (Gstottner et al., 2009). With respect to this discrepancy, in sports such as football it is common for the dominant leg to be defined as that which is commonly used to execute the kick (Dingenen et al., 2016). In volleyball this discrepancy has not been clarified with complete certainty. Thus, recent studies can be observed with volleyball players where no test is used to know the dominant leg, being usual to ask the subject verbally for the dominant limb (Fort-Vanmeerhaeghe et al., 2016; Varekova et al., 2011).

On the other hand, with regard to the surfaces used, it is worth noting the differences between the different surfaces in the coefficient of variation. In this study, the surfaces that showed the greatest differences between the dominant and non-dominant leg were Bosu ball and the balance disc. The greater coefficient of variation that occurs in these surfaces derives from the greater demand in the proprioceptive system and dictates the degree of difficulty of the different surfaces. In addition, Bosu ball also produced the greatest differences with respect to the dominant and non-dominant leg. According to previous studies the difference between both extremities is more obvious in a test that is more difficult for the locomotor system (Gstottner et al., 2009).

The results presented may be interesting for professionals and sports technicians in order to objectively know those surfaces that may result in greater differences in the balance between the different extremities due to their degree of complexity, as well as to know the surfaces that result in a greater demand for the proprioceptive system. Therefore, the results are relevant in order to propose training programs that have an objective degree of progression in their complexity.

**Strengths and limitations**

This is the first study that attempts to analyze the balance capacity of amateur volleyball players on different unstable surfaces that are usually used in rehabilitation programs and stability training. However, the limitations of this study must also be considered. In the first place, it is important to highlight the sample size, being necessary to increase the sample size in order to provide data with greater consistency. In addition, it is necessary to use other population groups in order to provide data that are comparable to the sample in this study. For this reason, it is necessary to inform that these are volleyball players with a low level of experience and, therefore, in future studies it would be necessary to analyze these results in professional volleyball players and show if there are similar results. This is because recent studies have shown that the higher the sporting level, the better the static balance, which could contribute to the prevention of injuries and the more effective performance in actions related to the game (Grygorowicz, Dzudziński, and Śliwowski, 2018). Finally, limitations related to the device used must be considered. Therefore, sensor components within the IMU, sensor calibration and sampling rate may have an effect on the results. However, all processes were carried out following the manufacturer's recommendations to avoid bias in this relationship.

Journal of Sport and Health Research 2020, 12(2):238-247

## 5. CONCLUSIONS

The different surfaces used produce a different demand in the proprioceptive system, with the balance table and Bosu ball being the surfaces with the highest demand. The differences can differ depending on the support leg used, causing more imbalance when using the dominant leg than the non-dominant one. However, in this research the magnitude of the differences has been relatively small and there does not appear to be a high consistency in the differences given on any of the surfaces. The magnitude of the difference should be considered in the training and rehabilitation protocols when proposing a balance training program. It would be advisable, before advancing in the use of unstable platforms, to check whether subjects have asymmetries and what their degree of imbalance is after an evaluation test to prescribe exercises according to the physical condition of the athlete. This is recommended because the differences between the dominant and non-dominant leg may be greater as the difficulty of the surface used increases.

## REFERENCES


1. Agostini, V., Chiaramello, E., Canavese, L., Bredariol, C., and Knaflitz, M. (2013). Postural sway in volleyball players. *Human Movement Science*, *32*(3), 445-456. doi:10.1016/j.humov.2013.01.002

2. Akinoglu, B., and Kocahan, T. (2018). Comparison of muscular strength and balance in athletes with visual impairment and hearing impairment. *Journal of exercise rehabilitation*, *14*(5), 765-770. doi:10.12965/jer.1836304.152

3. Alhusaini, A. A., Alnahdi, A. H., Melam, G., Aldali, A. Z., Al-Mutairi, M. S., and Alenzi, A. R. (2017). Normative values of y balance test and isometric muscle strength among saudi school children. *Physikalische Medizin Rehabilitationsmedizin Kurortmedizin*, *27*(3), 164-170. doi:10.1055/s-0043-105503

4. Bahr, R., and Bahr, I. A. (1997). Incidence of acute volleyball injuries: A prospective cohort study of injury mechanisms and risk factors. *Scandinavian Journal of Medicine and Science in Sports*, *7*(3), 166-171. doi:10.1111/j.1600-0838.1997.tb00134.x

5. Bressel, E., Yonker, J. C., Kras, J., and Heath, E. M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training*, *42(*1), 42-46.

6. Brophy, R., Silvers, H. J., Gonzales, T., and Mandelbaum, B. R. (2010). Gender influences: The role of leg dominance in acl injury among soccer players. *British Journal of Sports Medicine*, *44*(10), 694-697. doi:10.1136/bjsm.2008.051243

7. Brown, S. R., Brughelli, M., and Lenetsky, S. (2018). Profiling single-leg balance by leg preference and position in rugby union athletes. *Motor Control*, *22*(2), 183-198. doi:10.1123/mc.2016-0062

8. Cristofoli, E. L., Peres, M. M., Cecchini, L., Pacheco, I., and Pacheco, A. M. (2016). Comparison of the effect of proprioceptive training on the ankle of non-athletes and volleyball players. *Revista Brasileira De Medicina Do Esporte*, *22*(6), 450-454. doi:10.1590/1517-869220162206148309

9. Dingenen, B., Malfait, B., Nijs, S., Peers, K. H. E., Vereecken, S., Verschueren, S. M. P., . . . Staes, F. F. (2016). Postural stability during single-leg stance: A preliminary evaluation of noncontact lower extremity injury risk. *Journal of Orthopaedic and Sports Physical Therapy*, *46*(8), 650-657. doi:10.2519/jospt.2016.6278

10. Dorge, H. C., Andersen, T. B., Sorensen, H., and Simonsen, E. B. (2002). Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. *Journal of Sports Sciences*, *20*(4), 293-299.

11. Eerkes, K. (2012). Volleyball injuries. *Current Sports Medicine Reports*, *11*(5), 251-256. doi:10.1249/JSR.0b013e3182699037

12. Fort-Vanmeerhaeghe, A., Gual, G., Romero-Rodriguez, D., and Unnitha, V. (2016). Lower limb neuromuscular asymmetry in volleyball and basketball players. *Journal of Human Kinetics*, *5*0(1), 135-143. doi:10.1515/hukin-2015-0150

13. Grygorowicz, M., Dzudziński, W., and Śliwowski, R. (2018). Comparison of Static and Dynamic Balance at Different Levels of Sport Competition in Professional and Junior Elite Soccer Players. *Journal of strength and conditioning research*. August 21, 2019. doi: 10.1519/JSC.0000000000002476

14. Gstottner, M., Neher, A., Scholtz, A., Millonig, M., Lembert, S., and Raschner, C. (2009). Balance ability and muscle response of the preferred and nonpreferred leg in soccer players. *Motor Control, 13*(2), 218-231. doi:10.1123/mcj.13.2.218

15. Hadzic, V., Sattler, T., Veselko, M., Markovic, G., and Dervisevic, E. (2014). Strength asymmetry of the shoulders in elite volleyball players. *Journal of Athletic Training*, *49*(3), 338-344. doi:10.4085/1062-6050-49.2.05

16. Hammami, R., Behm, D. G., Chtara, M., Othman, A. B., and Chaouachi, A. (2014). Comparison of static balance and the role of vision in elite athletes. *Journal of human kinetics, 41*(1), 33-41.

17. Hrysomallis, C. (2007). Relationship between balance ability, training and sports injury risk. *Sports Medicine, 37*(6), 547-556. doi:10.2165/00007256-200737060-00007

18. Hudson, C., Garrison, J. C., and Pollard, K. (2016). Y-balance normative data for female collegiate volleyball players. *Physical Therapy in Sport, 22,* 61-65. doi:10.1016/j.ptsp.2016.05.009

19. Lesinski, M., Prieske, O., Demps, M., and Granacher, U. (2016). Effects of fatigue and surface instability on neuromuscular performance during jumping. *Scandinavian Journal of Medicine and Science in Sports*, *26*(10), 1140-1150. doi:10.1111/sms.12548

20. Magalhaes, J., Oliveira, J., Ascensao, A., and Soares, J. (2004). Concentric quadriceps and hamstrings isokinetic strength in volleyball and soccer players. *Journal of Sports Medicine and Physical Fitness*, *44*(2), 119-125.

21. Masuda, K., Kikuhara, K., Demura, S., Katsuta, S., and Yamanaka, K. (2005). Relationship between muscle strength in various isokinetic movements and kick performance among soccer players. *Journal of Sports Medicine and Physical Fitness, 45*(1), 44-52.

22. Mattes, K., Wollesen, B., and Manzer, S. (2018). Asymmetries of maximum trunk, hand, and leg strength in comparison to volleyball and fitness athletes. *Journal of Strength and Conditioning Research, 32*(1), 57-65.

23. McCurdy, K., and Langford, G. (2006). The relationship between maximum unilateral squat strength and balance in young adult men and women. *Journal of Sports Science and Medicine*, *5*(2), 282-288.

24. O'Donovan, K. J., Kamnik, R., O'Keeffe, D. T., and Lyons, G. M. (2007). An inertial and magnetic sensor based technique for joint angle measurement. *Journal of Biomechanics*, *40*(12), 2604-2611. doi:10.1016/j.jbiomech.2006.12.010

25. Pau, M., Loi, A., and Pezzotta, M. C. (2012). Does sensorimotor training improve the static balance of young volleyball players? *Sports Biomechanics*, *11*(1), 97-107. doi:10.1080/14763141.2011.637126

26. Promsri, A., Haid, T., and Federolf, P. (2018). How does lower limb dominance influence postural control movements during single leg stance? *Human Movement Science*, *58*, 165-174. doi:10.1016/j.humov.2018.02.003

27. Ruedl, G., Webhofer, M., Helle, K., Strobl, M., Schranz, A., Fink, C., . . . Burtscher, M. (2012). Leg dominance is a risk factor for noncontact anterior cruciate ligament injuries in female recreational skiers. *American Journal of Sports Medicine*, *40*(6), 1269-1273. doi:10.1177/0363546512439027

28. Sharma, A., Geovinson, S. G., and Sandhu, J. S. (2012). Effects of a nine-week core strengthening exercise program on vertical jump performances and static balance in volleyball players with trunk instability. *Journal of Sports Medicine and Physical Fitness*, *52*(6), 606-615.

Journal of Sport and Health Research 2020, 12(2):238-247

29. Sommer, H. M. (1988). Patellar chondropathy and apicitis, and muscle imbalances of the lower-extremities in competitive sports. *Sports Medicine*, *5*(6), 386-394. doi:10.2165/00007256-198805060-00004

30. Stephens, T. M., Lawson, B. R., and Reiser, R. F. (2005). Bilateral asymmetries in max effort single-leg vertical jumps. *Biomedical Sciences Instrumentation*, *41*, 317-322.

31. Teixeira, L. A., de Oliveira, D. L., Romano, R. G., and Correa, S. C. (2011). Leg preference and interlateral asymmetry of balance stability in soccer players. *Research Quarterly for Exercise and Sport*, *82*(1), 21-27. doi:10.1080/02701367.2011.10599718

32. Varekova, R., Vareka, I., Janura, M., Svoboda, Z., and Elfmark, M. (2011). Evaluation of postural asymmetry and gross joint mobility in elite female volleyball athletes. *Journal of Human Kinetics*, *29*, 5-13.

33. Verhagen, E., van der Beek, A., Twisk, J., Bouter, L., Bahr, R., and van Mechelen, W. (2004). The effect of a proprioceptive balance board training program for the prevention of ankle sprains - a prospective controlled trial. *American Journal of Sports Medicine*, *32*(6), 1385-1393. doi:10.1177/0363546503262177

34. Wang, J., Liu, Y., Fan, W., and Ieee. (2006). Design and calibration for a smart inertial measurement unit for autonomous helicopters using mems sensors. Ieee Icma 2006: *Proceeding of the 2006 Ieee International Conference on Mechatronics and Automation*, Vols 1-3, Proceedings, 956-+.

35. Weir, A., Darby, J., Inklaar, H., Koes, B., Bakker, E., and Tol, J. L. (2010). Core stability: Inter- and intraobserver reliability of 6 clinical tests. *Clinical Journal of Sport Medicine*, *20*(1), 34-38. doi:10.1097/JSM.0b013e3181cae924