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Non-Invasive Evaluation of Heart Rate Variability During Platform Balance Test

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Abstract

Neuromuscular activity also increases as we try to maintain our balance. Neuromuscular activity also causes changes in heart-rate-variability parameters. In the measurement of heart-rate-variability, recordings are generally taken for 5-minutes or longer. However, in recent years, ultra-short-term heart-rate-variability measurements from 5-minutes to 10-seconds have been made, especially in physical capacity measurement. The aim of the present study is to compare the heart-rate-variability parameters between the groups formed according to the performance before, during and, after the dynamic balance test. The sixty-three healthy males were recruited (age=25.8±3.3 years; height=176.6±5.5; weight=77.6±8.0) participated voluntarily. Heart-rate-variability was recorded for 60-seconds prior to testing. Afterwards, the participants were taken to the platform without shoes.Heart-rate-variability was recorded for 60-seconds at this time and 60-seconds at the end of the test. At the end of the balance test, according to the test procedure of the balance device, those who could stay in the A, B, C, D regions the most, that is, in the region closest to the center point, were grouped as the 1st group (n=38) and the others as the 2nd group (n=25). As a result of the study, a statistically significant difference was found between the groups in terms of heart rate variability changes for normalized low-frequency and normalized high-frequency significant differences were found between which groups ($p<0.05$). As a result, it was concluded in our study that participants with better balance skills had higher heart-rate-variability values. Considering that heart rate variability is also an indicator of fatigue, we can say that the implementation of exercises aimed at improving balance skills will contribute to the autonomic nervous system of the athletes.
Keywords: Autonomic nervous system, Physical capacity, Sympathetic activity, Balance

Platform Üzerinde Uygulanan Denge Testi Esnasında Kalp Atım Hızı Değişkenliğinin Non-Invazif Değerlendirilmesi

Öz

Denge sağlamaya çalışılırken, sinir-kas aktivitesi artar. Artan sinir-kas aktivitesi kalp atım hızı değişkenliği parametrelerinde değişikliklere neden olur. Kalp atım hızı değişkenliği ölçümünde genel olarak 5 dakika ve üzerinde kayıtlar alınmaktadır. Fakat son yıllarda özellikle fiziksel kapasite ölçümünde 5 dakikadan 10 saniyeye kadar ultra kısa süreli kalp atım hızı değişkenliği ölçümleri de yapılmaktadır. Bu çalışmanın amacı dinamik denge testi öncesi, sırası ve sonrasında, denge test platformunda belirlenen merkezde kalma süresine göre oluşturulan gruplar arasında kalp atım hızı değişkenliği değerlerinin karşılaştırılmasıdır. Çalışmaya 63 sağlıklı erkek (yaş=25.8±3.3 yıl; boy uzunluğu=176.6±5.5; vücut ağırlığı=77.6±8.0) katılımcı olarak alınmıştır. Kalp atım hızı değişkenliği test öncesinde 60 saniye boyunca kaydedilmiştir. Daha sonra katılımcılar ayakkabısız olarak denge platformuna çıkartılmıştır. Kalp atım hızı değişkenliği bu sırada 60 saniye ve test bitiminde 60 saniye olarak kaydedilmiştir. Denge testi sonunda denge cihazının test prosedürüne göre A, B, C, D bölgelerinden en fazla A bölgesinde yani merkez noktasına en yakın bölgede kalabilenler 1. grup (n=38), diğerleri 2. grup (n=25) olarak gruplandırılmıştır. Çalışma sonucunda normalize edilmiş düşük frekans ve normalize edilmiş yüksek frekans için kalp atım hızı değişkenliği değişiklikleri açısından gruplar arası anlamlı farklılık bulunmuştur ($p<0.05$). Sonuçta çalışmamızda denge becerisi daha iyi olan katılımcıların kalp atım hızı değişkenliği değerlerinin daha yüksek olduğu sonucuna varılmıştır. Kalp atım hızı değişkenliğinin yorgunluğun da bir göstergesi olduğu düşünüldüğünde, denge becerilerini geliştirmeye yönelik egzersizlerin uygulanmasının sporcuların otonom sinir sistemine katkı sağlayacağını söyleyebiliriz.
Anahtar kelimeler: Otonom sinir sistemi, Fiziksel kapasite, Sempatik aktivite, Denge

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INTRODUCTION

Postural control is defined as the act of maintaining, achieving or restoring a state of balance during any posture or activity (Pollock et al., 2000). Balance involves coordinated neuromuscular movements with signals from the visual, vestibular, and somatosensory structures to maintain the body's vertical position of the center of gravity on the base of support (Nashner, 2014). Balance skill is effective in providing many activities from postural posture to sportive performance. A horizontal position device is used to determine the dynamic balance skill. Weight is transferred to this device by climbing with two feet. At the end of the determined period, the performance is determined (Hrysomallis, 2011). Previous studies show that enhanced postural skills are accompanied by neuromuscular adaptations (Kneis et al., 2016; Taube et al., 2007; Zech et al., 2010). It is recommended to use balance exercises for postural and neuromuscular control improvements (Zech et al., 2010). Balance, neuromuscular control causes and increases changes in the autonomic nervous system (ANS) and therefore heart-rate-variability (HRV) to a certain extent (Kang & Hyong, 2014).

It is known that the cardiovascular system gives physiological responses such as tachycardia, increase in systolic blood pressure and cardiac output, and redistribution of blood flow to the heart and skeletal muscle against external physical or psychological stressors (Herd, 1991; Iellamo et al., 1997; Scalise et al., 2021) Unstable surfaces are an important source of external physical stress for the body. The HRV data of the athletes who had a good ability to cope with this stress were a better than the other group. Choi et. al (2010) in a study that compared the physiological values of talented golfers and less skilled golfers during the putting stroke, concluded that skilled golfers had better HRV values. They stated that this situation was associated with greater automaticity and reduced attention demands of the athlete with better ability to resist stress. The results of our study supported the findings of this study. Espinoza-(2021), in a study examining the relationship between the postural system and the autonomic system of Parkinson's patients, found evidence showing a relationship between the autonomic and postural systems. In the study, they reported that patients with more cardiac autonomic impairment had weaker postural control.

HRV, includes physiological changes between successive heartbeats controlled by the ANS (Baek et al., 2015), and performance context, exercise outcomes can be determined by HRV parameters evaluated ANS (Buchheit et al., 2010; Giles & Draper, 2018; Mosley & Laborde, 2015). Short-term and ultra-short term HRV measurement were evaluated after exercise, and consistent results were obtained (Kiviniemi et al., 2007; Makivić et al., 2013; Seiler et al., 2007). At the same time, there are studies on determining the timing to reach maximum performance in athletes (Chalencon et al., 2012; Manzi et al., 2009; Plews et al., 2012). In recent years, ultra-short-term heart-rate-variability measurements from 5-minutes to 10-seconds have been made, especially in physical capacity measurement (Esco et al., 2018; Nakamura et al., 2015). Balance ability and HRV are related to the functioning of the ANS (Billman, 2013; Robé et al., 2021). Balance ability refers to the ability to maintain a stable upright posture during standing or movement, and it requires the integration of sensory information from multiple systems, including the visual, vestibular, and somatosensory systems (Horak, 2006). HRV, on the other hand, refers to the variation in time between successive heartbeats and it is a measure of the activity of the ANS, which is composed of the sympathetic and parasympathetic nervous systems (PNS) (Shaffer & Ginsberg, 2017). Research has suggested that there is a correlation between balance ability and HRV.

Specifically, individuals with better balance ability tend to have higher levels of HRV, indicating a more balanced ANS with a greater capacity to adapt to changes in the environment (Robé et al., 2021). In contrast, individuals with impaired balance ability, such as those with Parkinson's disease or stroke, tend to have lower levels of HRV (Espinoza-Valdés et al., 2021) However, the exact nature of the relationship between balance ability and HRV is still being investigated, and more research is needed to fully understand the link between these two measures.

To the best of our knowledge, no research has been found using HRV data to determine the level of dynamic balance. In the balance test, we wonder about the importance of performance in maintaining vagal balance. The aim of the present study is to compare the HRV values between the groups formed according to the performance before, during, and after the dynamic balance test. We hypothesized that individuals with better balance performance would be more effective at suppressing sympathetic activity during and after testing, and better performing group would have significantly higher HRV values during the testing phases.

METHODS

Research Model

This research is a study conducted in a pre-test, test, post-test two-group comparative experimental design.

Research Groups

Sixty-seven healthy individuals who do recreational sports (walking, running, tennis, swimming, basketball, football) participated in the study. They were all male and had a medical report. Those who did not have a lower extremity injury in the last 6 months were included in the study. It was confirmed that the participants did not have a previous chronic disability that would affect their balance performance. A voluntary consent form was signed by the participants. Four participants were excluded from the study due to not completing all or part of the test. The final sample consisted of sixty-three participants (age=25.8±3.3 years; height=176.6±5.6 cm; weight=77.6±8.0 kg). Participants reported that they did not use medical drugs.

Data Collection Tools

Body Composition: Height was measured with Holtain Harpenden 601 stadiometer (Holtain Ltd., UK). Body weights was measured with an InBody brand 270 model (Biospace Co., S. Korea) body analyzer. The test was carried out according to the user manual and body mass index (BMI) was determined by formula weigh (kg) / height^2 (cm).

Balance Test: Sixty seconds of dynamic balance was measured by Sigma (Sigma Platform Balansowa, Poland). Participants stepped onto the balance platform with both feet. They tried to maintain their balance for 1 minute by looking at the screen in front of them. The device had a sensor that detects the change of position. There is also a system that determines the angle of oscillation. The results of the device were recorded in cm. The middle of the A region was considered the center.

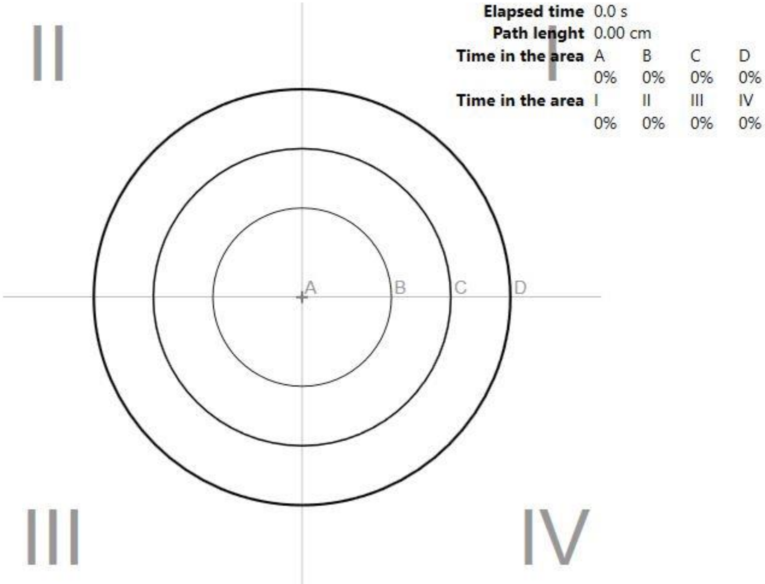

Figure 1. Balance Test platform program screenshot

Heart Rate Variability: Polar H7 band (Polar Electro, Kempele, Finland) was used for measurement of HRV. Polar V800 was used to collect HRV data. The correlation coefficient for calculating the RR interval of this device is high (intra-class correlation coefficient of >0.99) (Giles et al., 2016). HRV data was stored with Polar FlowSync Software (version 3.0.0.1337). The Kubios HRV standard for Mac (Biosignal Analysis and Medical Imaging Group, Department of Physics, University of Kuopio, Finland, version 3.1.0.1) was used for HRV analysis. Time-domain and frequency-domain values were processed. Recordings were transferred to PC with 1000 Hz sampling rates. Participants rested on their backs for 10 minutes before the test (Marek, 1996). Heart rate interval was recorded for sixty seconds separately before, during, and after the test. The spectral response was divided into 3 bands. Very low frequency (0.003–0.04 Hz), low frequency (0.04–0.15 Hz), and high frequency (0.15–0.4 Hz)(Makivić et al., 2013). Kubios 3.1 standard software was used for HRV analysis (Tarvainen et al., 2014). Evaluated time and frequency parameters for HRV:

- “Mean of R-R intervals (MeanRR)”,
- “Standard deviation (SDNN) of R-wave and R-wave intervals”,
- “Root mean square (RMSSD) of consecutive R-R intervals”,
- “Percentage of consecutive RR intervals that differ by more than 50 ms (PNN50)”,
- “Normalized absolute power of the low frequency band (LFnu)”,
- “Normalized absolute power of the high frequency band (HFnu)”,
- “Ratio of LF-HF power (LF/HF)”.

Ethical Approval

The experiments were approved by the Eskişehir Osmangazi University Research Ethics Committee (04.06.2020/07).

Collection of Data

Tests and applications were made on weekdays. It was held between the hours of 10:00 AM-12:00 AM. The temperature of the room where the measurement was made was 22-24°C and the humidity was 33-45%. The volunteers did not do vigorous exercise before the test day. It was requested not to use stimulants such as drugs on the test day. Researchers conducted the tests in groups consist of 6 participants. After the participants were informed and familiarized the test, HRV was recorded for 60 seconds (Esco et al., 2018; Nussinovitch et al., 2011). Afterwards, the participants were taken to the platform without shoes. HRV was recorded for 60-seconds during-test and 60-seconds after the test. Participants who could stay in the central region (A region) the most among the A, B, C, D regions were grouped as the 1st group (n=38), and the others as the 2nd group (n=25).

Analysis of Data

The mean and standard deviation of the research data were calculated. In relation to if the data distributed normally or not, for the kurtosis and skewness values, the Tabachnick and Fidell coefficients were used. For the comparison of age, height, weight, body fat, and BMI, t-test statistical method was used. Repeated two-factor analysis of variance (ANOVA) during the pre-test, test, and post-test was used to compare the 2 groups (3 times x 2 groups) HRV parameters. The Effect Size Eta squared (η^2) was calculated, which was considered small ($0.01>\eta^2$), medium ($0.01< \eta^2<0.06$), or large ($\eta^2>0.14$). Calculations were made with SPSS version 26 for mac OS, (SPSS Inc., Chicago, IL, USA). Significance level was accepted as $p<0.05$.

FINDINGS

The physical characteristics of the participants in the balance test and their oscillations for 60 seconds are shown below (Table 1). There was no significant difference between the groups in terms of age, height, weight, BMI, and body fat.

Table 1. Physical characteristics of the subjects (n=63)

Physical Characteristics	**G1 ($\bar{X}$ ± *SD*)**	**G2 ($\bar{X}$ ± *SD*)**	**t**
Age (years)	25.4 ± 2.9	26.5 ± 3.8	1.34
Height (cm)	176.7 ± 5.4	176.3 ± 5.8	0.31
Weight (kg)	77.9 ± 6.9	77.1 ± 9.6	0.38
BMI ($kg.m^{-2}$)	24.9 ± 1.5	24.8 ± 2.2	0.32
Body fat (%)	19.8 ± 4.4	19.7 ± 4.7	0.08
Balance test performance average (cm)	9.4 ± 4.5	9.7 ± 2.8	0.26

BMI: Body mass index, G1: group above average of balance test, G2: group below average of balance test.

The changes in HRV parameters of the groups in balance tests before, during, and after the test are shown in Table 2. As seen in Table 2, there is a significant difference between the groups for LFnu (F=3.9, η^2=0.06) and HFnu (F=3.9, η^2=0.06) values ($p<0.05$). Mean-RR (F=0.9, η^2=0.01), SDNN (F=0.5, η^2=0.01), RMSSD (F=1.5, η^2=0.02). PNN50 (F=1.9, η^2=0.03), and LF/HF (F=3.0, η^2=0.05) statistically significant difference was not found in the variables.

Table 2. The change of HRV parameters of the groups in balance tests before, during and after the test

	Group	Pre-test	Test	Post-test	F	ES
Mean RR (bpm)	G1	598.1 ± 86.1	577.1 ± 95.1	570.9 ± 71.9	0.9	0.01
	G2	572.7 ± 65.6	544.6 ± 68.9	556.2 ± 56.3		
SDNN (ms)	G1	34.6 ± 15.4	19.9 ± 10.9	34 ± 24.4	0.5	0.01
	G2	37.1 ± 16	18.1 ± 9	33.5 ± 20.9		
RMSSD (ms)	G1	21.8 ± 14.5	14.8 ± 11.4	25.2 ± 31.2	1.5	0.02
	G2	26.4 ± 19.3	17.2 ± 22	20.6 ± 11.7		
PNN50 (%)	G1	4.2 ± 5.6	2.6 ± 5.3	4.3 ± 6.8	1.9	0.03
	G2	6.6 ± 10.2	2.3 ± 7.3	4.8 ± 6.3		
LFnu (ms^2)	G1	80.8 ± 14.2	75 ± 17.5	76.7 ± 15.1	**3.9***	0.06
	G2	71.7 ± 21.9	77.9 ± 14.6	78.6 ± 13.4		
HFnu (ms^2)	G1	19.1 ± 14.1	24.8 ± 17.4	23.2 ± 15	**3.9***	0.06
	G2	28.1 ± 21.8	21.9 ± 14.4	21.3 ± 13.3		
LF/HF	G1	7.7 ± 6.7	5.3 ± 4	5.8 ± 5.4	3	0.05
	G2	5.2 ± 4.8	6.9 ± 7.9	5.5 ± 3.5		

MeanRR: Mean of R-R intervals, SDNN: Standard deviation of R-wave and R-wave intervals, RMSSD: Root mean square of consecutive R-R intervals, PNN50: Percentage of consecutive RR intervals that differ by more than 50 ms, LFnu: Normalized absolute power of the low frequency band, HFnu: Normalized absolute power of the high frequency band, LF/HF: Ratio of LF-HF power, * = p<0.05, G1: group above average, G2: group below average, ES=Effect size.

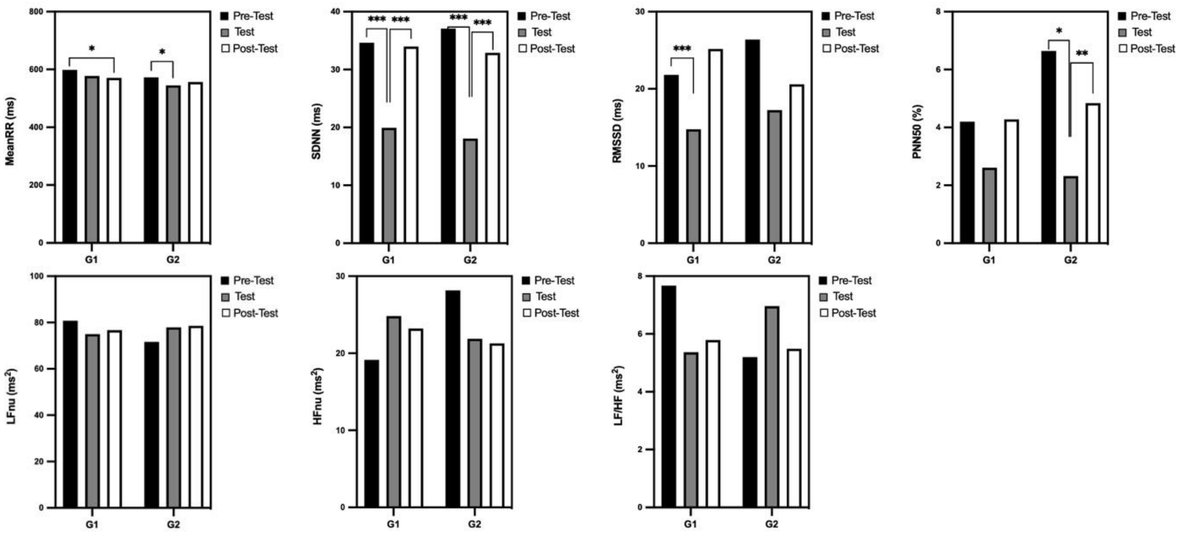

Figure 2. HRV changes in the balance test before, during and after the intra-group test

The changes in HRV parameters before, during, and after the intra-group test in the balance test are shown in Figure 2. In the balance test, pre-during-post test, for the G1 group intra-group comparisons; Mean-RR (G1: F=5.4**, η^2=0.13; G2: F=4.8*, η^2=0.16), SDNN (G1: F=14.8***, η^2=0.29; G2: F=22.1***, η2=0.48), RMSSD (G1: F=5.1*, η^2=0.12). PNN50 (G2: F=6.2*, η^2=0.20) statistically significant difference was found in the variables.

DISCUSSION AND CONCLUSION

The aim of present study is to determine whether there is a significant difference between groups formed according to dynamic balance test performance in terms of HRV values pre-during-post test. Our findings shown a statistically significant difference between the groups in terms of HRV changes for LFnu and HFnu (p<0.05). There was no significant difference for MeanRR, SDNN, RMSSD, PNN50, and LF/HF. There were differences for G1 and G2 among some HRV changes in differences between intra-group test stages. For SDNN, it was significant at the p<0.05 level for pre-during-post test in both groups. According to the findings of this study, we can accept the hypothesis that HRV values will significantly differ before and after the balance test and that there will be significant HRV changes among groups formed based on balance performance, in terms of both LF and HF.

As stated above, studies on balance and HRV are very limited. For this reason, the results of studies in which different groups were compared with HRV changes during exercise were used. There are some studies showing that those with better physical capacity have higher HRV values. In study conducted on elite athletes and sedentaries, Dixon et al., (1992) found that the LF/HF ratio returned to pre-exercise levels after exercise within 5-minutes recovery in athletes, while a 15-minute recovery time was required for sedentaries. At the beginning, it was seen that HF was higher in athletes. Middleton & De Vito, (2005) stated endurance training differs in cardiovascular autonomic control compared to sedentary. Higher MeanRR values ($p<0.001$) were observed in the trained group, conversely, the athletes exhibited higher LFnu ($p<0.001$) and lower HFnu ($p<0.01$) as a result, the LF/HF ratio was higher in the trained group ($p<0.01$). Biswas, (2020) did not record a significant difference in study which he compared the HRV values of cricketers and active and passive participants at rest.

It is widely thought that the HF peak reflects parasympathetic nerve activity and LF reflects sympathetic activity (Berntson et al., 1997; Billman, 2013; Malik, 1996). It was stated in some studies (Malliani et al., 1991; Pagani et al., 1986) that the LF/HF ratio could be used to measure the vagal balance between sympathetic and parasympathetic nerve activity. However, this is opposed in some studies (Berntson et al., 1997; Billman, 2011). Heart rate at rest can also affect HRV. The frequency domain analysis of HRV is similarly affected by the mean heart rate. Sacha & Pluta, (2008), found that LF was directly related, and HF was indirectly related to the subject's mean heart rate. As a result, they reported that LF/HF varied with heart rate, being lower in slower heartbeats and higher in faster heartbeats. Therefore, heart rate is independent of changes in cardiac autonomic nerve activity may affect the LF/HF as well. It has been reported in another study that respiratory rate increases the LF/HF ratio, but that it is unreliable in classifying fatigue (Saboul et al., 2014). It can be said that this may not be valid for tests where the respiratory rate does not increase much, such as the balance test.

Maheshkumar et al., (2017) have compared the short-term HRV between football players and sedentaries. MeanRR, SDNN, RMSSD, and PNN50 were significantly higher in the study group than the control group. HFnu showed significant higher value while LFnu and LF/HF of frequency domain parameters showed significant reduction among the football players. Janssen et al., (2004), in his study with cyclists and sedentary groups, had significantly higher SDNN, RMSSD, PNN50, and LF values in favor of cyclists while standing in a horizontal position, while HRV changes in standing measurements were not significant. Kayacan et al., (2023), examined the HRV values of professional handball players and sedentary players before and after the Wingate anaerobic strength test. There was no difference in parameters related to HRV frequency between the groups before and immediately after the test, but MeanRR ($p<0.05$) before the test and PNN50 ($p<0.05$) after the test increased in the athletes. Maior et al., (2015), investigated HRV values between elite volleyball players and individuals with recreational aerobic training with the progressive ramp treadmill test. RAT at rest showed lower values of MeanRR, RMSSD, LF and mean square of sequential difference of total power spectrum compared to volleyball players. There was no significant difference between the groups in terms of HF and LF/HF index. Another study confirms a faster return to hemodynamic equilibrium in physically active subjects, consistent with adaptations, compared to their sedentary counterparts (Oyeyemi et al., 2015). Sharma et al., (2015) evaluated HRV in the time and frequency domains between elite Nepali football players and non-athletes. Examined temporal and spectral HRV parameters determined from a 5-minute continuous ECG during supine rest RMSSD was higher in football players than non-athletes. Similarly, SDNN, the determinant of global HRV, was higher in players (p=0.003). Also, LF/HF, reflecting LFnu and sympatovagal balance, was significantly lower in players. Hammami et al., (2017) evaluated the effects of soccer training on short-term heart rate variability, blood pressure, and physical condition in untrained healthy adolescents. While HF and RMSSD showed a significant increase in the experimental group, LF sympathetic activity decreased. Our research results are consistent with the above research results. Findings related to higher HRV values and faster recovery time in those with high physical capacity resulted in favor of those with higher readiness in the balance skill measurement in our study.

There are several limitations of the present study. Firstly, only healthy young men were included in this study. Therefore, our results may not be generalizable to other populations like athletes, the elderly, females, with low back pain, etc. Secondly, the sample size was small. Finally, in present study were not assessment non-linear parameters of HRV.

In future studies will be required to investigate participants from populations with different demographics. In our study during 60-second dynamic balance test participants' eyes was open and both feet on the platform. There is a need for studies that apply different balance tests (eye-closed, one leg, dynamic balance, etc.). Also, in our study, a 1-minute ultra-short HRV measurement method was used. However, different stabilization times may be required for each individual due to different performance levels and sports branches (Plews et al., 2012). Therefore, longer-term HRV measurements would be beneficial in future studies.

With these results, it can be said that the group with better balance performance was more successful in suppressing the increased sympathetic activity during the test stages, due to the significant change in LFnu and HFnu values. It can be explained by the change in SDNN that the balance test in both groups significantly changed the balance of the general ANS for pre-test and post-test.

Conflicts of Interest: The authors declare that they have no conflict of interest.

Authors' Contribution: Study Design-TA-RA, Data Collection-TA-HT, Statistical Analysis-TA-RA, Manuscript Preparation-TA-RA-HT. All authors read and approved the final manuscript.

Ethical Approval
Ethics Committee: Eskişehir Osmangazi University Research Ethics Committee
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