Research Article

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Effects of Protocols with Resistance Bands and Foam Rollers on Dynamic Balance in Female Volleyball Players

Kadın Voleybolcularda Direnç Bantları ve Köpük Silindirlerle Yapılan Protokollerin Dinamik Denge Üzerine Etkileri

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ABSTRACT

The aim of this study was to investigate the effects of myofascial release cool down protocols performed with resistance band and foam rolling for 8 weeks on balance parameter in female volleyball players. Ethics committee approval was obtained (19/02/2024-004) with participant consent. The study involved 36 healthy female volleyball players (12 resistance band, 12 foam rolling, 12 control), aged 12.16±1.46 years, with at least two years of regular training. In addition to their regular 2-hour, 3-day weekly volleyball training, the experimental groups performed 20-minute myofascial release exercises twice weekly. The control group continued their routine cool down program. Y Balance Test was used for balance measurement. For statistical analyses, Paired sample t test was used for within-groups pre-post test comparisons. In the pre-test post-test comparison, a statistically significant increase was detected in the balance scores of the resistance band group ($p<0.05$). No significant difference was observed in terms of balance parameters in the foam rolling group and the control group ($p>0.05$). The results of the study indicate that resistance band exercises applied during the cool-down phase are effective in improving balance, whereas foam rolling application, which is a passive release method, does not create a similar positive effect on balance performance. These findings suggest that adding resistance-based myofascial exercises to cool-down protocols may be beneficial for enhancing neuromuscular control and stability in volleyball players.

Keywords: *Y balance test, Foam rolling, Resistance band, Fascia, Postural control*

ÖZ

Bu çalışmanın amacı, 8 hafta süreyle direnç bandı ve köpük silindir (foam rolling) ile yapılan miyofasyal gevşetme soğuma protokollerinin kadın voleybolculardaki denge parametresi üzerindeki etkilerini araştırmaktır. Katılımcı onamı ile etik kurul onayı alındı (19/02/2024-004). Çalışmaya, yaşları 12,16±1,46 yıl olan ve en az iki yıllık düzenli antrenman geçmişine sahip 36 sağlıklı kadın voleybolcu (12 direnç bandı, 12 köpük silindir, 12 kontrol) dahil edildi. Deneysel gruplar, haftada 3 gün, 2 saatlik düzenli voleybol antrenmanlarına ek olarak, haftada iki kez 20 dakikalık miyofasyal gevşetme egzersizleri yaptı. Kontrol grubu ise rutin soğuma programlarına devam etti. Denge ölçümü için Y Denge Testi kullanıldı. İstatistiksel analizler için, grup içi ön test-son test karşılaştırmalarında Eşleştirilmiş Örneklem t testi kullanıldı. Ön test-son test karşılaştırmasında, direnç bandı grubunun denge skorlarında istatistiksel olarak anlamlı bir artış tespit edildi ($p<0,05$). Köpük silindir grubu ve kontrol grubunda ise denge parametreleri açısından anlamlı bir fark gözlemlenmedi ($p>0,05$). Çalışmanın sonuçları, soğuma aşamasında uygulanan direnç bandı egzersizlerinin dengeyi geliştirmede etkili olduğunu, buna karşın pasif bir gevşetme yöntemi olan köpük silindir uygulamasının denge performansında benzer olumlu bir etki yaratmadığını göstermektedir. Bu bulgular, soğuma protokollerine direnç temelli miyofasyal egzersizlerin eklenmesinin, voleybolcularda nöromüsküler kontrol ve stabiliteyi artırmak için faydalı olabileceğini düşündürmektedir.

Anahtar Kelimeler: *Y Denge testi, Köpük rulo, Direnç bandı, Fasya, Postüral kontrol*

INTRODUCTION

Volleyball is a sport characterized by complex techniques and coordinated movement variations, requiring the optimization of balance (Ramirez-Campillo et al., 2020; Wang et al., 2025). It is a discipline whose foundation is formed by repeated Stretch-Shortening Cycle activities, particularly explosive vertical jumps and sudden lateral displacements. In competitive volleyball, dynamic balance is a pivotal determinant of athletic performance and injury prevention, particularly during the landing phase of jumps where rapid stabilization of the center of mass is required (Aagaard and Jørgensen, 1996; Hewett et al., 2016). However, the accumulation of neuromuscular fatigue post-exercise acutely degrades postural control by impairing mechanoreceptor sensitivity and proprioceptive feedback, leading to altered motor control strategies (Paillard, 2012). High tempo and explosive skills are especially evident in movements such as spiking and blocking (Calleja-Gonzalez et al., 2019; Palao et al., 2004). During these movements, fascial tissues store elastic energy like a spring and release it (Schleip and Müller, 2013). Volleyball players' performance depends on lower extremity functionality, the contractile strength of muscles, and the recoil capacity of connective tissues like fascia. Transferring energy without loss along the entire kinetic chain is possible only through the mechanical quality of fascial continuity (Schleip and Müller, 2013; Wilke et al., 2018)

Fascia is a dynamic structure composed of collagen tissues that adapt to tension in order to facilitate force transmission (Schleip et al., 2012). It is densely innervated with mechanoreceptors, which makes it a fundamental component of proprioception and postural control (Langevin and Huijing, 2009; Stecco et al., 2011). However, repetitive strain, trauma, or insufficient recovery periods during exercise can lead to fascial restrictions, thereby impairing movement efficiency and potentially increasing injury risk (Day et al., 2009). The myofascial system is a complex network of connective tissue enveloping muscles, bones, and organs, playing a critical role in maintaining structural integrity and facilitating movement (Schleip et al., 2012; Wiewelhove et al., 2018). Myofascial interventions exert their effects through both mechanical and neurophysiological mechanisms. Mechanically, myofascial release stimulates pressure changes within the fascia, promoting fluid exchange and reducing adhesions between tissue layers (Ajimsha et al., 2014). Neurophysiologically, the activation of mechanoreceptors during myofascial release reduces the excitability of alpha motor neurons, thereby alleviating muscle tension (Bradbury-Squires et al., 2015).

As in all sports disciplines, planning appropriate warm-up and cool-down protocols plays a critical role in both injury prevention and performance optimization in volleyball (Ebben et al., 2005). It is reported that foam roller applications integrated into cool-down protocols may enhance post-exercise recovery (Zhang et al., 2024). Furthermore, these applications have also been shown to improve parameters related to volleyball performance (Baumgart et al., 2019; Hammami et al., 2022; Su et al., 2017). Foam roller applications aim to reduce tissue resistance via the thixotropy mechanism by affecting the viscoelastic properties of fascial tissue (Behm et al., 2016; Cheatham et al., 2015). Ajimsha et al. (2015) stated that the foam roller mechanically promotes fascial fluid exchange and reduces tissue adhesions. Neurophysiologically, as demonstrated by Sullivan et al. (2013), slow, static pressure increases activation in muscle spindles, thereby reducing alpha motor neuron activity and consequently muscle tension. In addition to the foam roller, resistance band exercises also find widespread use due to their performance support and practical application (Aktürk and Tutar, 2024). It has been shown that these exercises activate muscles as effectively as traditional resistance training (Iversen et al., 2017; Jakobsen et al., 2012, 2014). Moreover, it is also reported that they can lead to improvements in balance performance by enhancing neuromuscular control and joint stability (Behm and Colado, 2012). Resistance band exercises apply a dynamic elastic load to the myofascial system, triggering neuromuscular activation and optimizing the longitudinal and lateral force transmission capacity of fascial tissue under active tension (Behm et al., 2016). Although the literature has demonstrated the separate positive effects of foam roller and resistance band applications, their mechanisms of action fundamentally differ (Behm and Colado, 2012; Bradbury-Squires et al., 2015). The foam roller is expected to affect parameters like balance primarily through passive myofascial release and neurophysiological tone reduction, while the resistance band is expected to do so through active stabilization and neuromuscular adaptation. However, studies directly comparing the relative effectiveness of these two different mechanisms on balance performance following chronic applications are insufficient (Behm et al., 2020).

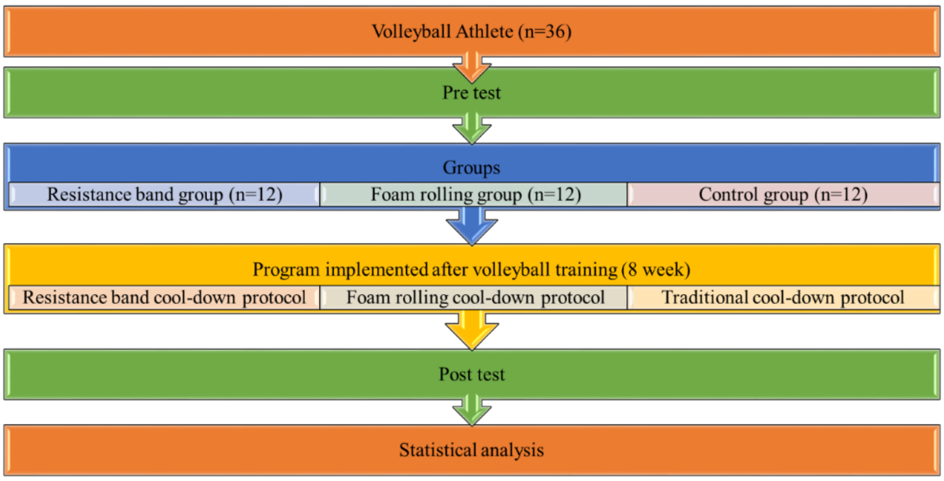
Given that female connective tissues exhibit unique mechanical properties influenced by hormonal fluctuations that affect collagen synthesis and fascial stiffness, it is essential to establish sex-specific protocols for myofascial interventions to optimize the 'spring' mechanism in the female athletic population (Zügel et al., 2018). It has also been reported that deficits in dynamic balance performance are a predictive factor for lower extremity injuries in female athletes (Pfile et al., 2013). Consequently, identifying the most effective myofascial modulation strategy whether through mechanical release or functional loading becomes crucial for optimizing performance in female athletes. However, comparative evidence is lacking regarding which modality best serves this population. Therefore, this study aims to directly compare the effects of these two popular interventions, which can be integrated into female volleyball players' cool-down routines, on lower extremity balance parameters, thereby providing an evidence-based perspective for practice.

METHOD

Procedure: Participants were randomly assigned to the experimental and control groups. To conduct the research, ethical approval was obtained from the Mersin University Sports Sciences Ethics Committee (19/02/2024-004), and an informed consent form prepared accordance with the Helsinki Declaration was signed by all participants. To minimize assessment bias, a single-blind procedure was implemented. The outcome assessors who conducted the performance tests and collected data were blinded to the group assignments of the participants. These assessors were not involved in the administration of the training protocols, and the participants were instructed not to disclose their group allocation during the testing sessions. After the pre-tests were completed, the volleyball players were randomly divided into three groups. All groups continued to participate in regular volleyball training. The interventions were applied following these training sessions. The interventions for all groups are presented in Figure 1.

Figure 1

Study Design



Participants: An a priori power analysis was conducted using G*Power software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Germany). Due to the lack of directly comparable prior research evaluating these specific interventions in volleyball players, the sample size was determined based on a moderate effect size, consistent with Cohen's (2013) recommendations. The calculation was based on the F-test family (ANOVA: Fixed effects, omnibus, one-way) to detect differences in score changes between groups. To detect a moderate effect size (Cohen's f = 0.30) with an alpha error probability of 0.05 and a statistical power of 0.80, the analysis indicated that a minimum of 30 participants would be required. To account for potential dropouts, a total of 36 participants (12 per group) were recruited (Faul et al., 2007). The study population was selected based on specific inclusion and exclusion criteria to ensure group homogeneity. Inclusion criteria were: (1) being an active volleyball player for at least 2 years, and (2) volunteering to participate in the study. Exclusion criteria were: (1) having a history of lower/upper limb musculoskeletal injury in the past 6 months, (2) use of any performance-enhancing supplements or medications that could affect neuromuscular performance, and (3) missing more than two training sessions during the intervention period. Following baseline assessments, participants were randomly allocated into three groups using a simple randomization procedure. A random number sequence was generated electronically, and participants were assigned to the resistance band, foam rolling, or control group in a 1:1:1 ratio. The allocation was performed by a researcher not involved in the outcome assessments to maintain blinding. The study cohort consisted of healthy female volleyball players (n=36; 12 resistance band, 12 foam rolling, 12 control) with a mean age of 12.16 ± 1.46 years, who had been engaged in regular training for at least two years. All groups participated in volleyball training sessions lasting 2 hours per day, 3 days per week (including warm-up and cool-down periods). The experimental groups (resistance band and foam rolling) performed 20-minute myofascial release exercises during the cool-down phase following the first and last training sessions of the week. On the second training day of the week, they followed the routine traditional cool-down program. The control group continued with their traditional cool-down program on all three training days of the week. All participants successfully completed the study protocol without any reported injuries or dropouts.

Body Height/ Mass Measurement: Body mass was measured using a digital scale with a sensitivity of 0.02 kg (Seca), and stature was assessed in an upright standing position using a stadiometer with a precision of 0.01 cm (Holtain Ltd. U.K). BMI was calculated from body weight and height (kg/m^2).

Training Program: In this study, foam rolling aimed to increase ankle mobilization, which is critical for anterior access to Y-Balance test, by reducing tissue viscosity; while resistance band applications aimed to stabilize postural control required during Y-Balance test by triggering neuromuscular activation. The resistance band application included the following exercises: Light Jogging/Walking, Banded Cat-Cow, Banded Overhead Squat, Banded Pull-Aparts, Shoulder Stretch with Band, Triceps Stretch with Band, Banded Good Morning, Banded Hip Flexor Stretch, Banded Glute Bridge, Quadriceps Band Stretch, Calf Stretch, and Deep Breathing. The difficulty level was adjusted by changing the resistance of the band. A 5kg band was used for the first two weeks, a 10kg band for the next three weeks, and a 15kg band for the final three weeks. Upper extremity exercises in the resistance band protocol were incorporated to promote total body neuromuscular activation and to maintain kinetic chain integrity. The foam rolling myofascial release application included the following exercises: Light Jogging/Walking, Quad Roll, Shin Roll, Lateral Shin Mobilization, Hamstring Roll, Regular Calf Roll Out, Kneeling Calf Massage, Iliotibial Band Roll, Adductor Roll, and Deep Breathing (Cengiz et al., 2022; Öztürk, 2023). Detailed information regarding the specific intervention protocols applied to each study group is explicitly presented in Appendix 1.

Balance Measurement: The Y-Balance Test is the most frequently utilized tool for assessing postural balance, employed to detect dynamic balance changes in adolescents aged 11 to 19 years (Schwiertz et al., 2019; Suzin et al., 2023). Wang et al. (2025) used the Y-Balance test in volleyball players and reported that dynamic balance ability is directly related to both vertical jump height and the risk of non-contact injury. The balance assessment was conducted using the Lower Quarter Y-Balance Test. The athletes were instructed to reach the maximum distance in the anterior, posteromedial, and posterolateral directions. The researcher performing the Y Balance Test measurements was blinded to group allocation. The test was performed barefoot. Participants stood on one leg behind the starting line and pushed the reach indicator with the other leg to achieve the maximum possible distance in the specified directions. The test apparatus is configured with a 135-degree angle between the anterior and posterior directions, and a 90-degree angle between the two posterior directions. Prior to the test, participants' leg length was measured from the anterior superior iliac spine (ASIS) to the medial malleolus in a supine position to normalize the reach distances (Gribble and Hertel, 2013). This method is a widely used practical protocol for assessing limb length in clinical and anthropometric studies (Beattie et al., 1990). All measurements were performed in a standard position by a single experienced researcher to minimize measurement error. Linek et al. (2017), in their study investigating the reliability of the Y-Balance Test, recommended a protocol involving nine trials (comprising six practice trials and three recorded measurements). Following this recommendation, prior to the official test, each participant performed six practice trials for each lower extremity in all three reach directions to account for the learning effect associated with this dynamic balance motor skill (Neves et al., 2017). Subsequently, three test trials were administered for data analysis. To mitigate the effects of fatigue, three measurements were first taken in the anterior direction for both legs, followed by three measurements in the posteromedial direction, and finally three in the posterolateral direction. The best score achieved in each of the three distinct directions was used for evaluation. The maximum reach distance was determined by reading the value on the tape measure at the edge of the reach indicator, corresponding to the point reached by the most distal part of the foot (Neves et al., 2017). Trials were considered invalid if the participant touched the floor with the reaching foot, lost balance, kicked the indicator, or failed to return to the starting position. The Y-Balance Test outcomes were calculated as a composite score, normalized to leg length, using the following formula “Composite score (cm) = [(Anterior + Posteromedial + Posterolateral) / (3 × Limb Length)] × 100”. In the literature, higher values obtained by normalizing the Y-Balance test scores (reach distances) relative to the participant's leg length are considered an indicator of superior dynamic balance, functional stability, and neuromuscular control (Gribble et al., 2012; Plisky et al., 2006).

Statistical Analyses: The suitability of the variables for normal distribution was examined using visual (histograms and probability plots) and analytical methods (the Shapiro-Wilk test). The Paired Samples t-test was used for within-group pre-post test comparisons. A significance level of $p < 0.05$ was accepted for all analyses. To adjust for potential baseline differences in dynamic balance, an Analysis of Covariance (ANCOVA) was employed for inter-group comparisons, using the pre-test Y-Balance scores as the covariate, post-test scores as the dependent variable, and groups as the fixed factor.

RESULTS

The demographic characteristics of the participants, including age, body length, and leg length, are presented in Table 1. To determine baseline homogeneity, a One-Way ANOVA was conducted on the pre-test Y-Balance composite scores. Although the analysis revealed no statistically significant differences between the groups at baseline ($p = 0.426$), the calculated effect size indicated a nearly medium practical variance (η_p^2 =0.050). Therefore, to rigorously control for these initial differences, pre-test scores were assigned as a covariate in the subsequent main analyses.

Table 1

Descriptive Statistics of Participant Characteristics for All Groups

Groups	Parameters	Mean	SD
Resistance band (n=12)	Age (year)	12.08	1.38
	Body length (cm)	158.67	8.75
	Leg length (cm)	86.67	5.21
	BMI (kg/m²)	19.19	2.58
	Training Year	2.25	0.72
Foam rolling (n=12)	Age (year)	12.08	1.38
	Body length (cm)	160.33	7.11
	Leg length (cm)	89.50	4.21
	BMI (kg/m²)	19.94	2.75
	Training Year	3.17	0.95
Control (n=12)	Age (year)	12.25	1.55
	Body length (cm)	162.92	5.11
	Leg length (cm)	90.75	4.90
	BMI (kg/m²)	19.61	5.19
	Training Year	3.13	0.65

Table 2

The Pre-Test and Post-Test Mean and Standard Deviation and Paired Samples T Test Results for All Groups

Groups	Test	Descriptive Statistics	Y balance			
			Composite score (cm)	t	Sig.	Effect Size (Cohen's d)
Resistance band group ***(n=12)***	Pre-test	Mean	78.78	-4.975	0.001*	0.43 (Small)
		SD	6.71			
	Post-test	Mean	81.66			
		SD	6.65			
Foam rolling group ***(n=12)***	Pre-test	Mean	76.03	-0.552	0.592	0.24 (Small)
		SD	10.1			
	Post-test	Mean	78.45			
		SD	13.42			
Control group ***(n=12)***	Pre-test	Mean	80.41	0.066	0.948	-0.01 (None)
		SD	7.39			
	Post-test	Mean	80.33			
		SD	6.75			

*p<0.05 indicates statistical significance. Note: Effect sizes were interpreted as: small (0.20), medium (0.50), and large (0.80).

Table 2 presents the intra-group comparisons of Y Balance Test composite scores. The resistance band group demonstrated a statistically significant improvement from pre-test (78.78 ± 6.71 cm) to post-test (81.66 ± 6.65 cm) ($p < 0.001$). In contrast, no significant changes were observed in the foam rolling group ($p = 0.592$) or the control group ($p = 0.948$). These findings suggest that the resistance band protocol was effective in eliciting positive adaptations in dynamic balance. However, ANCOVA analysis controlling for pre-test differences showed no statistically significant difference between groups ($F(2.32)=0.224$, $p=0.801$). This finding indicates that the resistance band protocol did not provide a significant advantage over other groups.

Table 3 presents the results of the One-Way ANOVA comparing the balance scores across the three groups. The analysis revealed no statistically significant differences between the groups ($F = 0.347$, $p = 0.709$). Although the preliminary One-Way ANOVA indicated no statistically significant differences between the groups at baseline ($p=0.426$), the calculated effect size ($\eta_p^2 =0.050$) revealed a nearly medium variance of practical importance. Therefore, to rigorously account for these initial baseline discrepancies and prevent them from skewing the post-intervention outcomes, an Analysis of Covariance (ANCOVA) was subsequently conducted, assigning the pre-test balance scores as a covariate

Table 3

One-way ANOVA Results for Comparison of Y Balance Difference Scores Between Groups

Measurement		Sum of Squares	df	Mean Square	F	p (Sig.)	Effect Size (η_p^2)
Y balance Composite Scores Pre-test	Between Groups	117.729	2	58.865	0.876	0.426	0.0504 (Nearly medium effect size)
	Within Groups	2217.317	33	67.191			
	Total	2335.047	35				

Note: (η_p^2) (Partial Eta Squared) interpretation: small (0.01), medium (0.06), and large (0.14).

A one-way Analysis of Covariance (ANCOVA) was conducted to determine whether there were significant differences between the intervention and control groups on post-test Y-Balance scores, after controlling for baseline pre-test scores. The analysis revealed that the covariate, the pre-test Y-Balance score, was significantly related to the post-test score, $F(1, 32) = 9.025$, $p = 0.005$, $\eta_p^2 = 0.220$. This indicates that baseline dynamic balance performance had a significant effect on post-intervention outcomes. However, after adjusting for these initial differences, there was no statistically significant main effect of the group on the post-test Y-Balance scores, $F(2, 32) = 0.224$, $p = 0.801$, $\eta_p^2 = 0.014$. These results demonstrate that neither the resistance band nor the foam rolling protocol provided a statistically significant superiority over the control group regarding between-group comparisons when baseline discrepancies were strictly controlled (Table 4).

Table 4

Analysis of Covariance (ANCOVA) Results for Post-Test Y-Balance Composite Scores Controlling for Pre-Test Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	715.505[a]	3	238.502	3.296	0.033	0.236
Intercept	504.746	1	504.746	6.975	0.013	0.179
Y Balance Composite Scores Pre-test	653.087	1	653.087	9.025	0.005	0.220
Grup	32.420	2	16.210	0.224	0.801	0.014
Error	2315.706	32	72.366			
Total	234283.771	36				
Corrected Total	3031.210	35				

a. R Squared = 0.236 (Adjusted R Squared = 0.164)

DISCUSSION

The primary aim of this study was to compare the effects of an 8-week active resistance band protocol versus passive foam rolling on dynamic balance in female volleyball players. The main finding is that no significant between-group differences were observed after controlling for baseline scores. However, the resistance band group showed a statistically significant within-group improvement ($p < 0.001$) with a small effect size (Cohen's $d = 0.43$). In contrast, neither the foam rolling nor the control group demonstrated significant changes. The lack of a significant between-group effect indicates that the resistance band protocol was not statistically superior to the other conditions at the group level. Nevertheless, the isolated pre-to-post improvement in the resistance band group does not allow for a conclusion of advantage over other conditions; it merely indicates a within-group effect worthy of further investigation, whereas passive foam rolling did not elicit a similar benefit in balance performance.

Cool-down is crucial for supporting an athlete's recovery process and reducing the risk of injury. Various active cool-down strategies, such as resistance bands and foam rolling, are used by athletes to achieve optimal performance levels and protect against injuries by facilitating proper recovery (Guillot et al., 2019). Myofascial release induces changes in the elastic properties of the muscle, increases mitochondrial biogenesis, and enhances blood flow to the muscles by promoting angiogenesis or the reopening of occluded vessels (Schroeder and Best, 2015). Consequently, the myofascial release technique is also utilized for regeneration and recovery following activity (Anderson et al., 2017; Okamoto et al., 2014).

Volleyball is a team sport involving complex skills and requiring constant movement. Balance is one of the attributes that enables the execution of many physical or sporting movements, stopping, changing direction, moving, and maintaining a stable body position (Siedentop et al., 2019). A study evaluating ankle functions and postural control variables in volleyball players with stable ankles reported that volleyball players have better ankle joint range of motion and postural control (Özdemir and Mutlu, 2024). In our study, the balance composite scores of the resistance band group were observed to improve positively. Another study investigating lower extremity dynamic balance in volleyball players also used the Y Balance Test, reported that dynamic balance can contribute to overall physical performance, and recommended that volleyball players include dynamic balance monitoring in their training programs (Wang et al., 2025). A study investigating balance performance in female volleyball players recommended the implementation of neuromuscular training programs to improve balance (Vitale et al., 2019). Popovic (2019) stated that self-administered myofascial release exercises have a positive effect on balance performance in volleyball players. The modest but statistically significant improvement in the resistance band group—with a small-to-medium effect size—suggests that resistance training may have some positive effects on neuromuscular control and functional balance, although these effects should be interpreted cautiously given the lack of a significant between-group difference.

It can be hypothesized that the active nature of resistance band exercises may support dynamic balance by providing a stimulus to mechanoreceptors (Stecco et al., 2011). However, since neurophysiological markers were not recorded in this study, these mechanisms remain speculative and should be investigated in future research. Literature suggests that resistance training using unstable or elastic devices enhances motor unit recruitment and proprioception (Aktürk and Tutar, 2024; Behm and Colado, 2012). In the context of volleyball, which requires rapid adjustments in body position for spiking and blocking (Palao et al., 2004), it is possible that the resistance band protocol likely served as a form of "neuromuscular recovery," reinforcing the motor patterns required for stability even during the cool-down phase. This aligns tentatively with the findings of Wang et al. (2025) and Hammami et al. (2022), who emphasized the positive transfer of dynamic resistance training to physical performance and balance in volleyball players.

A critical finding of this study is the lack of significant balance improvement in the foam rolling group. While foam rolling is widely advocated for increasing flexibility and reducing perceived fatigue (Wiewelhove et al., 2019), its impact on dynamic balance remains debated. Our results indicate a neutral effect, which can be attributed to the physiological mechanism of foam rolling. Foam rolling primarily targets tissue hydration and the reduction of fascial adhesions through pressure, which induces a relaxation response and downregulation of muscle spindle activity (Behara and Jacobson, 2017; Bradbury-Squires et al., 2015). While this relaxation is beneficial for recovery, it may not provide the necessary excitatory stimulus to the neuromuscular system to acutely enhance postural control. This distinction is vital for coaches; if the goal is pure relaxation, foam rolling is appropriate, but for enhancing proprioceptive stability, it appears insufficient on its own. The lack of significant balance improvement in the foam rolling group aligns with the theoretical distinction wherein passive modalities like foam rolling are primarily associated with tissue-level effects such as hydration and relaxation, rather than neuromuscular facilitation (Behara and Jacobson, 2017; Bradbury-Squires et al., 2015).

In the present study, no statistically significant change was observed in the balance parameters of the control group. This finding indicates that routine volleyball training alone (whether without a specific cool-down protocol or with a standard one) does not spontaneously provide additional acute or chronic benefits for balance performance. Therefore, to potentially improve dynamic balance, specific neuromuscular stimuli and protocols requiring active participation such as the resistance band protocol used in this study may need to be incorporated beyond routine technical training.

Based on the study results, an important practical implication can be derived for coaches. In volleyball, which is characterized by high tempo and injury risk, it may be a beneficial strategy to include resistance band exercises that maintain proprioceptive engagement in the cool-down protocol. However, given the lack of significant differences between the groups, coaches should be cautious in interpreting these findings as definitive evidence of superiority. The choice to use such active methods, either in addition to or instead of relying solely on passive methods like foam rolling, should depend on the session's primary goal (e.g., recovery vs. neuromuscular maintenance).

Limitations: The present study has some limitations. First, the study sample consisted solely of female volleyball players, which limits the generalization of the findings to male athletes or adult professional players. Second, the absence of a long-term retention test prevents us from determining whether the balance gains in the resistance band group were sustained beyond the 8-week intervention period. Third, future studies could incorporate electromyography (EMG) to directly measure muscle activation patterns during these cool-down protocols to better understand the underlying neurophysiological mechanisms. Finally, a potential limitation of this study is the structural difference between the intervention protocols, specifically the inclusion of upper extremity exercises in the resistance band group, which were intended for general activation but may differ from the exclusively lower-extremity focus of the foam rolling application. Furthermore, due to the simple random assignment of the participants, the groups could not be perfectly homogenized based on their baseline Y-Balance scores. Consequently, the control group exhibited relatively higher pre-test values compared to the intervention groups. Even though an ANCOVA model was used to statistically control for these baseline differences, this initial discrepancy stands as a limitation of the study design.

CONCLUSION

In conclusion, an 8-week cool-down protocol utilizing resistance band exercises resulted in significant within-group improvement in dynamic balance among female volleyball players, whereas foam rolling and traditional cool-down methods did not yield similar benefits. However, the absence of a significant main effect of group indicates that the resistance band protocol did not demonstrate statistically superior effects compared to the other interventions at the group level. These findings suggest the potential utility of incorporating active resistance-based exercises into cool-down routines, but do not provide conclusive evidence that they are "more effective" than passive myofascial release techniques such as foam rolling for improving dynamic balance in this population. Coaches and athletic trainers may consider integrating resistance band exercises into their post-training routines to support the functional stability of athletes.

Author Contribution:

1. **İnci KESİLMİŞ**: Idea/Concept, Design, Auditing, Data Processing, Analysis - Commentary, Article Writing, Critical Review
2. **Gülten METİNER**: Idea/Concept, Design, Data Processing,
3. **Feride Berfin YELBAŞI**: Idea/Concept, Design, Article Writing
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Date: 19/02/2024

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Appendix 1

Resistance band, foam rolling and traditional cool down program

Resistance Band/Foam Rolling Group Applications			
Resistance Band Program			
Duration	**Exercise**	**Target Area**	**Set/Duration-Reps**
2 Minutes	Light Jogging/Walking	Whole Body (Cardio)	120 s
2 Minutes	Banded Cat-Cow	Spine	10-12 Reps
2 Minutes	Banded Overhead Squat	Shoulder, Chest, Hip, Ankle	8-10 Reps
2 Minutes	Banded Pull-Aparts	Shoulder, Back	12-15 Reps
1 Minute	Shoulder stretch with band	Shoulder, Chest	20-30s, 2 reps
1 Minute	Triceps stretch with band	Triceps	20-30s, 2 reps
2 Minutes	Banded Good Morning	Hamstring, Hip	10-12 Reps
2 Minutes	Banded Hip Flexor Stretch	Front Hip	30-45s / Each Leg
2 Minutes	Banded Glute Bridge	Hip (Glutes)	12-15 Reps
2 Minutes	Quadriceps band stretch	Quadriceps (Front Thigh)	20-30s, 4 reps
1 Minute	Calf stretch	Calf (Gastrocnemius/Soleus)	20-30s, 2 reps
1 Minute	Deep Breathing	Whole Body and Mind	60 s
Foam Rolling Program			
Duration	**Exercise**	**Target Area**	**Set/Duration-Reps**
2 Minutes	Light Jogging/Walking	Whole Body (Cardio)	120 s
2 Minutes	Quad Roll	Thigh (Anterior/Quadriceps)	2 sets, 15s work / 15s rest
2 Minutes	Anterior Shin Roll	Shin (Anterior Tibialis)	2 sets, 15s work / 15s rest
2 Minutes	Lateral Shin Mobilization	Lateral Shin (Peroneals)	2 sets, 15s work / 15s rest
2 Minutes	Hamstring Roll	Thigh (Posterior)	2 sets, 15s work / 15s rest
2 Minutes	Calf Roll Out	Calf (Posterior)	2 sets, 15s work / 15s rest
2 Minutes	Kneeling Calf Massage	Calf (Posterior)	2 sets, 15s work / 15s rest
2 Minutes	Iliotibial Band Roll	Lateral Thigh (IT Band)	2 sets, 15s work / 15s rest
2 Minutes	Adductor Roll	Inner Thigh (Adductors)	2 sets, 15s work / 15s rest
2 Minutes	Deep Breathing	Whole Body and Mind	60 s
Traditional Cool-Down Program			
5 Minutes	Light Jogging/Walking	Whole Body (Cardio)	120 s
10 Minutes	Static stretching	Major muscle groups	30 sec, 2 sets
	Quadriceps stretch (standing, holding ankle with hand)	Anterior thigh	40 sec, 2 sets
	Hamstring stretch (sitting, one leg extended)	Posterior thigh	40 sec, 2 sets
	Calf stretch (leaning against a wall)	Calf (gastrocnemius/soleus)	40 sec, 2 sets
	Hip flexor stretch (standing lunge position)	Front hip	40 sec, 2 sets
	Glute stretch (sitting, pulling one knee to chest)	Hip (glutes)	40 sec, 2 sets
	Upper back and shoulder stretch (arms crossed in front)	Upper back, shoulder	40 sec, 2 sets
	Triceps stretch (arm bent overhead)	Triceps	40 sec, 2 sets
3 Minutes	Deep breathing	Whole body and mental relaxation	3 Minutes
2 Minutes	Very slow-paced free walking	Whole body (active recovery)	2 Minutes