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Effect of a 4-month flywheel resistance training program on lower limb stability of male and female volleyball players

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Abstract

Introduction: Lower limb stability is critical for athletic performance, especially in sports that require quick movements, changes of direction, and high-impact activities like volleyball. Adequate lower limb stability not only improves sports performance but also aids in the prevention of lower extremity injuries. As a result, developing lower limb stability is critical for volleyball players who want to enhance their performance while minimizing their risk of injury.
Aim: The aim of the study consisted in investigating the effects of an alternative method for developing dynamic stability of the lower limbs by using a flywheel (isoinertial) training device.
Material and method: The study employed a randomized controlled trial design, with participants assigned to either an experimental group that underwent the flywheel resistance training program or a control group that performed the standard training intervention. Lower limb dynamic stability of the subjects was assessed using the Y Balance Test™. Composite reach distance index (CRD) has been calculated for both left (CRDL) and right (CRDR) legs. The intervention protocol consisted in 32 sessions using a flywheel training device.
Results: Regarding the female groups, the results for the right lower limb show that when removing the covariate effect (initial test values), the impact of the intervention on the final values was significant $F=4.69$, $p=.042$, $\eta^2=.18$. In the case of the left lower limb, the intervention was again statistically significant $F=12.3$, $p=.002$, $\eta^2=0.37$. In the case of the male groups right lower limb, controlling for initial values, there is a statistically significant effect of the intervention on the final dynamic stability values for the experimental group $F=5.73$, $p=.03$, $\eta^2=.21$. The same was observed for the left lower limb CRD of the male experimental group $F=8.53$, $p=0.008$, $\eta^2=0.29$.
Conclusions: The results of the covariation analysis showed a statistically significant lower limb stability improvement in the experimental groups compared to the control groups. This increase was recorded for both the right and left lower limbs of the male and female experimental groups.

***Key words**: flywheel, isoinertial, volleyball, training, stability*

Rezumat

Introducere: Stabilitatea membrelor inferioare este esenţială pentru performanţa sportivă, în special în sporturile care necesită mişcări rapide, schimbări de direcţie şi acţiuni cu impact ridicat, cum ar fi voleiul. O stabilitate adecvată a membrelor inferioare nu numai că aduce o îmbunătățire a performanţelor sportive, dar ajută şi la prevenirea accidentărilor membrelor inferioare. Prin urmare, dezvoltarea stabilităţii membrelor inferioare este esenţială pentru jucătorii de volei care doresc să îşi îmbunătăţească performanţele, minimizând în acelaşi timp riscul de accidentare.
Scop: Scopul studiului a constat în investigarea efectelor unei metode alternative de dezvoltare a stabilităţii dinamice a membrelor inferioare prin utilizarea unui dispozitiv de antrenament cu volant (izoinerţial).

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Material și metodă: Studiul a fost de tip intervenţional , participanţii fiind repartizaţi fie la un grup experimental care a urmat programul de antrenament folosind dispozitivul cu volant, fie la un grup de control care a efectuat pregătirea standard din timpul sezonului. Stabilitatea dinamică a membrelor inferioare a subiecţilor a fost evaluată cu ajutorul testului de echilibry Y. Indicele compus de amplitudine (CRD) a fost calculat atât pentru piciorul stâng (CRDL), cât și pentru cel drept (CRDR). Protocolul de intervenţie a constat din 32 de sesiuni folosind un dispozitiv de antrenament cu volant.
Rezultate: În ceea ce priveşte grupele feminine, rezultatele pentru membrul inferior drept arată că, atunci când se elimină efectul covariatelor (valorile iniţiale ale testului), impactul intervenţiei asupra valorilor finale a fost semnificativ F=4.69, p=.042, η^2=.18. În cazul membrului inferior stâng, intervenția a fost din nou semnificativă din punct de vedere statistic F=12.3, p=.002, η^2=.37. În cazul membrului inferior drept al grupelor masculine, controlând valorile inițiale, există un efect statistic semnificativ al intervenţiei asupra valorilor finale ale stabilității dinamice pentru grupul experimental F=5.73, p=.03, η^2=.21. Acelaşi lucru a fost observat şi pentru CRD la nivelul membrului inferior stâng al grupului experimental masculin F=8.53, p=.008, η^2=.29.
Concluzii: Rezultatele analizei de covariaţie au arătat o îmbunătățire semnificativă a stabilității membrelor inferioare, din punct de vedere statistic, la grupele experimentale în comparaţie cu grupele de control. Această creştere a fost înregistrată pentru ambele membre inferioare la grupele experimentale masculine și feminine.

Cuvinte cheie: *volant, izoinerţial, volei, antrenament, stabilitate*

Introduction

Lower limb stability is critical for athletic performance, especially in sports that require quick movements, changes of direction, and high-impact activities like volleyball (Mesfar et al., 2022). Adequate lower limb stability not only improves sports performance but also aids in the prevention of lower extremity injuries. As a result, developing lower limb stability is critical for volleyball players who want to enhance their performance while minimizing their risk of injury.

One emerging training method that has gained attention in the field of sports science is flywheel resistance training (Raya-Gonzalez et al., 2023). Unlike traditional resistance training methods that utilize fixed weights or resistance, flywheel training employs specialized equipment that generates variable resistance throughout the entire range of motion (Raya-Gonzalez et al., 2023). This unique feature allows for greater muscle activation and force production, leading to enhanced strength gains and improved athletic performance (Murton et al., 2023; Sanudo et al., 2022). Previous research has highlighted the effectiveness of flywheel training in improving strength and power parameters in various athletic populations (Buonsenso et al., 2023; Filetti et al., 2023; Sanudo et al., 2022). However, the specific effects of flywheel training on lower limb stability in volleyball players are not well understood. By filling this knowledge gap, the current study aims to provide evidence-based insights into the potential of flywheel resistance training as a targeted approach for enhancing the stability of the lower limbs in male and female volleyball players.

Aim and purpose

The aim of the study consisted in investigating the effects of an alternative method for developing dynamic stability of the lower limbs by using a flywheel (isoinertial) training device.

The following hypothesis was formulated: Implementing a flywheel training protocol will lead to significant improvements in lower limb dynamic stability of volleyball players compared to traditional training methods.

Material and method

The study begun with a number of 64 subjects, 34 females and 30 males from 4 teams in first and second Romanian volleyball league. After applying the inclusion and exclusion criteria, 24 male and 24 female subjects remained. 4 equal groups have been formed as follows: one male control group (MC), one female control group (FC), one male experimental group (MEX) and one female experimental group (FEX), each numbering N=12 subjects.

The Y Balance Test™ was used for evaluating the lower limb dynamic stability of the subjects. Composite reach distance index (CRD) has been calculated for both left (CRDL) and right (CRDR) legs. At the start of the competitive season in September, the subjects' initial evaluations were conducted. After the experimental groups had the 4-month intervention, the final evaluation was carried out in December to January. The conventional training program recommended by the team coaches was used for the control groups. This included 2 weight training sessions per week.

For the experimental groups, the intervention consisted in 32 flywheel device training sessions in total. The exercise chosen was the squat. There were 2 sessions per week for a span of 16 weeks. The structure of the flywheel training protocol was divided into 4 cycles, one for each month of training.

- First month - 3 sets of 12 repetitions/session;
- Second month – 4 sets of 10 repetitions/session;
- Third month – 4 sets of 8 repetitions/session;
- Fourth month – 5 sets of 6 repetitions/session.

The inertial load of the flywheel plate was 0.050 kgm^2.

Results

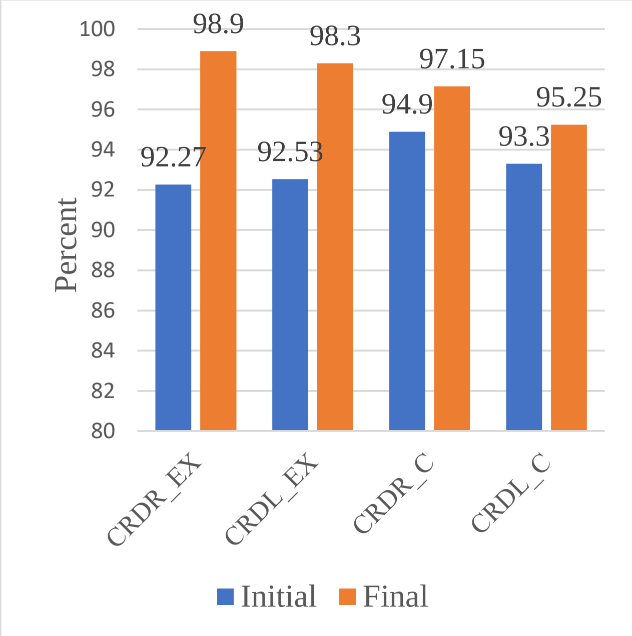
Lower limb dynamic stability parameters were measured using the Y balance test. The composite reach distance index CRD was calculated for both lower limbs. We used paired-samples t-test in order to compare the means obtained by the study groups for the CRD variable. We used the Shapiro-Wilk statistical test in order to check the distribution of the values of the target parameter and the results proved that we had normal distribution for the groups.

In Table I we have centralized the means (M) and standard deviations (AS) for the pairs formed by the initial and final CRD values of both lower limbs for both the experimental and control groups. In addition to these values, we also have in the last 3 columns the results of the paired sample t-test. The table contains the data for the female groups.

Table I. Mean, standard deviation and t-test values for the lower limb composite reach distance index of female groups

G		Pairs	M(%)	SD (%)	t	df	p
Ex.	P 1	CRDR_F_FEX- CRDR_I_FEX	98.09 92.27	5.02 6.63	4.8 64	11	.000**
	P 2	CRDL_F_FEX- CRDL_I_FEX	98.30 92.53	4.76 7.21	4.8 64	11	.000**
Ct.	P 3	CRDR_F_FC- CRDR_I_FC	97.15 94.90	3.66 4.22	2.9 56	11	.013*
	P 4	CRDL_F_FC- CRDL_I_FC	95.25 93.33	3.66 3.92	2.9 00	11	.014*

Note: * - values are significant at a threshold p <.05
CRDR–composite reach distance right leg
CRDL- composite reach distance left leg
FEX- female experimental group
FC- female control group
F- final testing
I- initial testing



CRDR–composite reach distance right leg
CRDL- composite reach distance left leg
EX – experimental group
C- control group
Figure 1. Evolution of the composite reach distance index for the female, experimental and control groups

In the case of the experimental group, comparing the initial (M=92.27, SD=6.63) and final (98.09, SD=5.02) CRD values of the right lower limb, we observe an increase of 5.82 units, which is highly statistically significant (t=4.86, df=11, p<.001). The difference in the mean CRD of the left lower limb of 5.77 is also highly statistically significant (t=4.86, df=11, p<.001).

For the control group, the mean value of right lower limb stability (M=94.9, AS=4.22) improved by 2.25 compared to the final values (M=97.15, SD=3.66), the increase is statistically significant (t=2.95, df=11, p<.05). A similar statistically significant increase of 1.92 (t=2.9, df=11, p<.05) is observed for the final CRDL (M=95.25, SD=3.66) compared to the initial CRDL (M=93.33, SD=3.92).

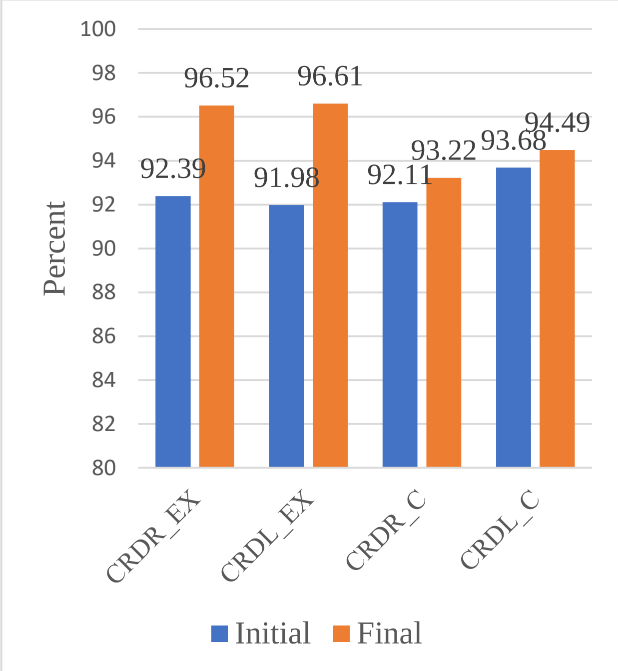
In the graph above we see how the increase in CRD for both lower limbs in the experimental groups is greater than in the control groups. Also the statistical significance of the improvement is stronger for the experimental group (p<.001) compared to the control group (p<.05). In terms of symmetry of mean stability, the control group shows close CRD values for both the initial and the final tests. Looking at the control group in contrast, we observe differences in the lower limb stability index at both baseline and final tests.

We followed the same procedure for the means and standard deviations of the CRD values of the male groups. Paired sample t-test results were entered in the last 3 columns of Table II.

Table II. Mean, standard deviation and t-test values for the lower limb composite reach distance index of male groups

G	Pairs		M (%)	SD (%)	t	Df	p
Ex.	P 1	CRDR_F_MEX- CRDR_I_MEX	96.52 92.39	5.06 5.42	7.93	11	.000**
	P 2	CRDL_F_MEX- CRDL_I_MEX	96.61 91.98	5.43 5.53	5.56	11	.000**
Ct.	P 3	CRDR_F_MC- CRDR_I_MC	93.22 92.11	5.69 4.39	.97	11	.353
	P 4	CRDL_F_MC- CRDL_I_MC	94.49 93.68	4.79 4.47	.91	11	.380

Note: ** - values are significant at a threshold p <.001
CRDR–composite reach distance right leg
CRDL- composite reach distance left leg
MEX- male experimental group
MC- male control group
F- final testing
I- initial testing



CRDR–composite reach distance right leg
CRDL- composite reach distance left leg
EX – experimental group
C- control group
Figure 2. Evolution of the composite reach distance index for the female, experimental and control groups

In the experimental group, we had the same upward trend as in the female group, the mean CRD for the right lower limb increased from M=92.39, SD=5.42 to M=96.52, SD=5.06, with a statistically significant value of 4.13 (t=7.93, df=11, p<.001). A significant improvement (t=5.56, df=11, p<.001) was also seen in the mean CRDL which went from an initial value of M=91.98, SD=5.53, to M=96.61, SD=5.43 and a difference of 4.63.

The control group on the other hand had no increase in the mean CRD from a statistically point of view, the CRDR only increased by 1.11 (t=.97, df=11, p=.35) from the value M=92.11, SD=4.39, to the final value M=93.22, SD=5.69. In the case of the left lower limb, the increase was smaller but close, with a statistically insignificant difference of .81 (t=.91, df=11, p=.38), the initial mean being 93.68 SD=4.47, and the final M=94.49, SD=4.79.

As can be seen in the graph above, the improvement in the dynamic stability index is noticeable in the experimental group for both lower limbs (p<.001). The control group also shows increases in this parameter, but these are lower and statistically insignificant (p>.05). In terms of symmetry between the left and right lower limb, we note small differences for both groups at baseline. These differences fade for the experimental group, with the mean CRDs being almost equal. In the control group this correction is not observed, parameters only increase to a small extent.

In order to control for baseline test values and to check the effect of the intervention, we used ANCOVA covariate analysis. For this test, the covariate was regarded as the initial test value, the independent variable was the group (experiment/control), and the dependent variable was the final test value.

For the use of the ANCOVA test we checked the following two conditions:

1. The distribution of the data to be normal using the Shapiro-Wilk test;
2. Homogeneity of the regression.

Both conditions were verified and satisfied for the male and female groups.
After running the ANCOVA test for CRDR and CRDL in both male and female groups, we have centralized the results in Table III.

Table III. ANCOVA analysis results for the final parameter of dynamic stability of experimental groups
Independent variable: Group

	Dependent cariable	df	Mean Square	F	p	Partial Eta Squared
F	CRDR	1	37.03	4.68	.042*	.183
	CRDL	1	74.42	12.30	.002*	.369
M	CRDR	1	55.60	5.72	.026*	.214
	CRDL	1	73.73	8.52	.008*	.289

Note: * - values are significant at a threshold p <.05
CRDR–composite reach distance right leg
CRDL- composite reach distance left leg

Regarding the female groups, the results for the right lower limb show that when removing the covariate effect (baseline test values), the impact of the intervention on the final values was significant F=4.69, p=.042, η^2=.18. In the case of the left lower limb, the intervention was again statistically significant F=12.3, p=.002, η^2=.37.
In the case of the male groups right lower limb, controlling for baseline values, there was a statistically significant effect of the intervention on the final dynamic stability values for the experimental group F=5.73, p=.03, η^2=.21. The same was observed for the left lower limb CRD of the male experimental group F=8.53, p=.008, η^2=.29.

Discussions

The findings of the study on the effect of a 4-month flywheel resistance training program on lower limb stability of male and female volleyball players align with previous research in the field. Several studies have examined the impact of resistance training on lower limb stability and reported similar positive outcomes.
For instance, a study by Granacher et al. (2013) investigated the effects of a 12-week resistance training program on balance and stability in older adults. The results showed significant improvements in dynamic stability measures following the intervention. This supports the notion that resistance training can positively influence stability-related outcomes (Granacher et al., 2013).
Emery et al. (2005) conducted a randomized controlled trial investigating the effects of a 12-week lower limb resistance training program on stability in female soccer players. The results showed significant improvements in balance and stability measures, suggesting that resistance training can enhance lower limb stability in female athletes (Emery et al., 2005).
Luebbers et al. (2003) examined the effects of an 8-week lower extremity resistance training program on stability in collegiate basketball players. The intervention group demonstrated significant improvements in postural stability and balance compared to the control group. This study emphasizes the positive impact of resistance training on lower limb stability in male athletes, consistent with the findings of the present study (Luebbers et al., 2003).
Moreover, a meta-analysis conducted by Lesinski et al. (2015) examined the effects of resistance training on balance and postural control in various populations, including athletes. The analysis revealed a significant improvement in balance and stability measures following resistance training interventions (Lesinski et al., 2015). These findings suggest that resistance training can have a beneficial impact on stability across different populations, further supporting the results of the study.
Furthermore, a study by Hrysomallis (2011) focused specifically on lower limb stability in athletes and explored the effects of resistance training on balance and stability performance. The findings indicated that resistance training interventions led to significant improvements in lower limb stability measures among athletes (Hrysomallis , 2011). This corroborates the results of the current study, which demonstrated positive effects of the flywheel resistance training program on lower limb stability in both male and female volleyball players.
In summary, the results of the present study align with previous research indicating that resistance training interventions can enhance lower limb stability. The findings are consistent with studies conducted on various populations, including older adults and athletes, highlighting the effectiveness of resistance training in improving stability-related outcomes. The positive effects observed in the current study contribute to the growing body of evidence supporting the incorporation of resistance

training programs to enhance lower limb stability in volleyball players and potentially in other athletic populations as well.

Conclusions

The study's hypothesis has been fully confirmed, according to the result that has been supplied. Covariation analysis was used to find statistically significant evidence that the researchers' hypothesis was correct. When compared to the control groups, the study showed that the lower limb stability index in the experimental groups had significantly improved. Both the right and left lower limbs of the male and female individuals in the experimental groups showed this improvement. The findings indicate that the study's flywheel training protocol is a successful strategy for developing lower limb stability. The regimen has also showed potential in promoting strength, another characteristic of this kind of exercise. In conclusion, the study's results show that the flywheel training program can be used as an effective strategy for enhancing lower limb stability and offer significant support for the hypothesis.

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