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Abstract

Introduction: Measurements of postural stability are carried out for the prevention of injuries and for rehabilitation of athletes who have sustained traumatic injuries. The aim of the study was to assess postural stability measured in static and dynamic conditions in 14-year-old girls, of whom some were training volleyball, and some were not. Materials and Methods: The study involved a group of 30 girls aged 14, attending volleyball classes. This group was compared with the control group (n = 30) of girls of the same age who regularly participated only in regular physical education (PE) classes. The tests were conducted twice. The first examination was conducted at the end of September 2021 and then repeated at the beginning of January 2022, at a primary school with an extended sport curriculum in Krakow. The Flamingo Balance Test was used to determine postural stability in static conditions, and the Y-Balance Test – to measure postural stability in dynamic conditions. Results: Statistically significant differences between the results obtained during the first and the second examination were found for four parameters: Y-ANT R ($p = 0.025$) and FBT L ($p = 0.001$) in the group of girls practicing volleyball and (FBT L ($p = 0.002$) and FBT R ($p = 0.030$) in the regular PE group. Conclusions: Neither examination showed any statistically significant differences in the intergroup YBT values. The largest difference of 4% was recorded for the Y-POST-MED R range in the second examination.

Keywords

postural stability, training, team games, injuries

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Article

Assessment of postural stability of 14-year-old girls training volleyball

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Abstract: Introduction: Measurements of postural stability are carried out for the prevention of injuries and for rehabilitation of athletes who have sustained traumatic injuries. The aim of the study was to assess postural stability measured in static and dynamic conditions in 14-year-old girls, of whom some were training volleyball, and some were not. Materials and Methods: The study involved a group of 30 girls aged 14, attending volleyball classes. This group was compared with the control group (n = 30) of girls of the same age who regularly participated only in regular physical education (PE) classes. The tests were conducted twice. The first examination was conducted at the end of September 2021 and then repeated at the beginning of January 2022, at a primary school with an extended sport curriculum in Krakow. The Flamingo Balance Test was used to determine postural stability in static conditions, and the Y-Balance Test – to measure postural stability in dynamic conditions. Results: Statistically significant differences between the results obtained during the first and the second examination were found for four parameters: Y-ANT R ($p = 0.025$) and FBT L ($p = 0.001$) in the group of girls practicing volleyball and (FBT L ($p = 0.002$) and FBT R ($p = 0.030$) in the regular PE group. Conclusions: Neither examination showed any statistically significant differences in the intergroup YBT values. The largest difference of 4% was recorded for the Y-POST-MED R range in the second examination.

Keywords: postural stability, training, team games, injuries.

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1. Introduction

Balance is one of the most important coordination motor skills in humans. Virtually, every motor task contains its elements, which makes it an integral part of everyday life and makes it essential for the maintenance of the physical health [1]. Maintenance of a stable body posture includes elements related to movement control, spatial orientation, and action of various forces on the human body [2].

Measurements of stability on a fixed surface are mainly used in sports as part of injury prevention and in the process of post-injury rehabilitation. Such measurements may affect the clinical evaluation of various motor functions, among others. Owing to such measurements, the acquired knowledge, along with the awareness of the requirements for a specific sport discipline, may be decisive for athlete's qualification for future training without the risk of injury [3]. Tests that examine static and dynamic balance are used to assess postural stability. Balance studies in dynamic conditions are particularly important due to their similarity to those found in sports, especially in team games [4, 5]. Over the past few years, the Y-Balance Test has gained great popularity among dynamic balance studies. The results of this test enable assessment of the risk of falls and consequent injuries, as well as estimation of their resultant deficits [6].

In view of the above, the aim of this study was to test and evaluate postural stability measured in static and dynamic conditions in 14-year-old girls training and not training volleyball. This is an interesting area, definitely worth exploring because of a small number of studies on the ability to maintain balance in volleyball, and the possibility of using FBT and YBT that is rather unpopular in Poland. Additionally, the choice of the subjects' age is not accidental. This is the period of adolescence characterized by increased changes taking place in the young girls' bodies, a point which additionally encouraged the authors to undertake this research problem. Individual development of motor coordination at each stage of volleyball training may affect the training process, technique improvement and selection of effective strategies during the game [7, 8].

2. Material and Methods

2.1. Participants

The study involved a group of 30 girls aged 14, attending volleyball classes, participating in 10 hours of training per week (group T). This group was compared with the control group (n = 30) of girls of the same age, who regularly participated only in regular physical education classes, 4 hours per week in total (group NT). The purposive sampling method was used. The characteristics of the studied girls are presented in Table 1. The tests were conducted twice. The first examination was conducted at the end of September 2021 and then repeated at the beginning of January 2022 at a primary school with expanded sports curriculum in Krakow. The research project gained an approval of the Bioethics Committee of the Regional Medical Chamber in Cracow (Opinion No. 175/KBL/OIL/2020 of July 14, 2020). The examinations were non-invasive in nature and were conducted with the approval of the school management after obtaining consent from the subjects' parents. The scope of the study did not exceed the scope of the standard physical education preventive tests for teenagers and was accordant with the Declaration of Helsinki issued by the World Medical Association [9].

Table 1. Characteristics of the examined girls.

	T	NT
Variables	Mean ± SD	Mean ± SD
Age (years)	13.90 ± 0.31	13.90 ± 0.31
Height (m)	1.65 ± 0.05	1.61 ± 0.06
Body weight (kg)	54.10 ± 7.16	52.90 ± 9.09

The training and the non-training girls did not significantly differ with respect to somatic parameters ($p \leq 0.05$).

2.2. Procedure

Postural stability studies were conducted in static and dynamic conditions at 10.00 a.m. without any warm-up. Prior to the testing, the following somatic parameters were measured:

- body height, using an anthropometer with an accuracy of 0.01 m;
- body weight, using a medical scale with an accuracy of 0.1 kg.

Laterality was diagnosed with the use of the 'step forward' test [10]. Only right-legged girls were eligible for the study.

The Flamingo Balance Test (FBT) was used to examine static postural stability. The duration of the test was measured with an accuracy of 0.01 s for each limb from the moment the limb was raised until the balance was lost and the leg was lowered to regain support. Three trials were performed for each lower limb. The best result was recorded on the study subject card [11].

The Y-Balance Test (YBT) was used to examine dynamic postural stability. The Y-Balance Kit was used for measurements (Figure 1) [12–14]. In addition, the relative length of the lower limbs was measured with an accuracy of 1 cm.

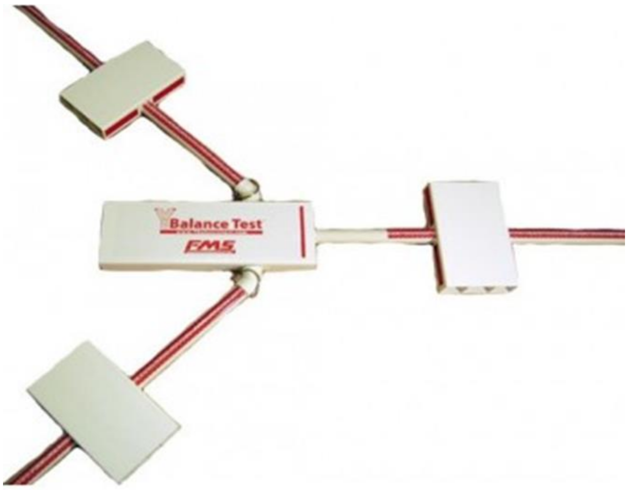

Figure 1. An original Y-Balance Kit [14].

When standing on the central board of the instrument, the examined girls had to move mobile indicators with the leg contralateral to the supportive one, for as far as possible, in three directions: anterior, posterolateral, and posteromedial. After the required movements in all 3 directions had been executed, the lower limb returned to the main platform of the instrument. There were 3 attempts in each direction. After each correctly performed test, the distance between the central point of the central board and the point of the indicator nearest to this central point was measured with an accuracy of 0.5 cm, The percentages for the right and left lower limbs were calculated using the formula by Pliski et al. [14]:

$$\text{MAX D (\%)} = [EL/ LL] \times 100$$

where:
MAXD (%) = the maximum reach distance in one direction in %,
EL = distance of reach in one direction,
LL = relative length of the extremity.

The next step was to calculate the global percentages for both lower limbs. The obtained values were inserted into the formula by Pliski et al. [14]:

$$\text{YBT-CS(\%)} = [(AN + PM + PL) / (LL \times 3)] \times 100$$

where:
YBT-CS (%) = YBT composite reach score, A
N = anterior reach, PM = posteromedial reach,
PL = posterolateral reach,
LL = relative length of the extremity.

Global YBT results were compared with the so-called better vs worse postural stability index. Ranks 0-1 were used in the comparative tables. 1 was attributed to subjects whose result was higher than the 89.6% limit [6], while 0 was attributed to those whose result did not exceed this defined limit. A total result higher than 89.6% was indicative of a better postural stability of the subject and a lower risk of injuries, while the result below this value was indicative of a poorer postural stability and a higher risk of injury. The results obtained in this way were summed up and calculated as percentages.

2.7. Statistical analyses

Basic statistical characterization of the tested variables was performed. Mean values and standard deviations were calculated. Using the Shapiro-Wilk test, the distributions of the tested variables were calculated in the first stage of the analysis. It was assumed that the distribution of the analyzed variables would be different from the normal one with the calculated p value of ≤ 0.05. When the normal distribution was found for both variables in a given pair, the t-test for dependent samples was used to compare the means in one group, in which the results were measured twice, and the t-test for independent samples – to compare the means in two independent groups. When the absence of normal distribution for at least one variable from the pair was found, a non-parametric pair sequence Wilcoxon test was performed for two dependent samples, while the non-parametric U-Mann-Whitney test for two independent samples was used for group comparison. The significance level of $p \leq 0.05$ was assumed.

3. Results

The results of the examinations in the groups of 30 T girls and 30 NT girls are presented in the following tables with a brief comment.

Table 2. Means and standard deviations of the examined variables in groups T and NT in the first and second examination.

	Variables	Examination I			Examination II		
		n	$\bar{x}$	**SD**	**n**	$\bar{x}$	**SD**
T	Y-ANT L [%]	30	73.53	7.56	30	72.36	9.44
	Y-POST-MED L [%]	30	93.55	10.61	30	94.40	9.09
	Y-POST-LAT L [%]	30	100.65	7.64	30	100.36	8.48
	Y-CS L [%]	30	90.14	6.42	30	90.60	6.21
	FBT L [s]	30	9.07	5.57	30	12.45	11.03
	Y-ANT R [%]	30	69.73	8.00	30	72.23	7.03
	Y-POST-MED R [%]	30	98.54	7.82	30	99.81	6.90
	Y-POST-LAT R [%]	30	95.66	10.70	30	95.82	9.86
	Y-CS R [%]	30	89.24	7.69	30	87.15	7.81
	FBT R [s]	30	10.54	7.36	30	11.88	8.62
NT	Y-ANT L [%]	30	72.84	6.68	30	72.20	5.39
	Y-POST-MED L [%]	30	97.50	8.33	30	98.63	9.12
	Y-POST-LAT L [%]	30	100.08	8.20	30	100.98	7.43
	Y-CS L [%]	30	89.24	7.49	30	89.04	7.93
	FBT L [s]	30	11.59	11.30	30	14.13	12.96
	Y-ANT R [%]	30	71.85	7.86	30	71.43	5.51
	Y-POST-MED R [%]	30	97.58	8.26	30	95.89	8.27
	Y-POST-LAT R [%]	30	97.34	10.00	30	98.47	9.18
	Y-CS R [%]	30	88.49	7.68	30	89.90	6.14
	FBT R [s]	30	13.04	14.29	30	16.13	14.73

Legend: Y-ANT L [%] – percentage value of the left lower limb reach in the anterior direction; Y-POST-MED L [%] – percentage value of the left lower limb reach in the posteromedial direction; Y-POST-LAT L [%] – percentage value of the left lower limb reach in the posterolateral direction; Y-CS L [%] – percentage value of the YBT global score for the left lower limb; FBT L [s] – the Flamingo Balance Test score for the left lower limb; Y-ANT R [%] – percentage value of the right lower limb reach in the anterior direction; Y-POST-MED R [%] – percentage value of the right lower limb reach in the posteromedial direction; Y-POST-LAT R [%] – percentage value of the right lower limb reach in the posterolateral direction; Y-CS R [%] – percentage value of the YBT global score for the right lower limb; FBT R [s] – the Flamingo Balance Test score for the right lower limb.

Table 3 shows the results of the W Shapiro-Wilk compatibility test of the examined variables. A non-normal distribution was found for the following variables: body weight, FBT L and FBT R in the T group and Y-ANT R, Y-CS R, FBT L and FBT R in the NT group. Therefore, the Wilcoxon test was used in these cases to assess the statistical significance of the differences found between the first and the second examination.

Table 3. Results of the W Shapiro-Wilk distribution normality test of the analyzed variables of both examined groups.

Variables	T (n = 30)		NT (n = 30)	
	W	*p*	W	*p*
HEIGHT [m]	0.936	0.073	0.975	0.683
WEIGHT [kg]	0.908	0.013*	0.977	0.728
Y-ANT L [%]	0.951	0.181	0.951	0.184
Y-POST-MED L [%]	0.975	0.682	0.954	0.220
Y-POST-LAT L [%]	0.981	0.843	0.975	0.689
Y-CS L [%]	0.977	0.731	0.980	0.815
Y-ANT R [%]	0.981	0.851	0.910	0.015*
Y-Y-POST-MED R [%]	0.976	0.707	0.982	0.870
Y-Y-POST-LAT R [%]	0.946	0.136	0.966	0.440
Y-CS R [%]	0.970	0.543	0.920	0.027*
FBT L [s]	0.845	0.000*	0.749	0.000*
FBT R [s]	0.868	0.001*	0.811	0.000*

*$p \leq 0.05$

The results presented in Table 4 allow concluding that as far as the four parameters are concerned, both the first and the second examination show some statistically significant differences between the obtained results: Y-ANT R (p = 0.025) and FBT L (p = 0.001) in the T group and (FBT L (p = 0.002) and FBT R (p = 0.030) in the NT group.

Table 4. Comparative analysis of results of examinations I and II using the non-parametric Wilcoxon matched pairs test.

Pair of variables	Wilcoxon's pair sequence test			
	N	**T**	**Z**	**P**
Y-ANT R [%] T Examination I & Y-ANT R [%] T Examination II	27	96.00	2.23	0.025*
Y-ANT R [%] NT Examination I & Y-ANT R (%) NT Examination II	29	190.00	0.59	0.552 NS
Y-CS R [%] T Examination I & Y-CS R [%] T Examination II	30	185.00	0.98	0.329 NS
Y-CS R [%] NT Examination I & Y-CS R [%] NT Examination II	29	138.00	1.72	0.086 NS

Pair of variables	Wilcoxon's pair sequence test			
	N	**T**	**Z**	**P**
FBT L [s] T Examination I & FBT L [s] T Examination II	30	141.50	1.87	0.001*
FBT L [s] NT Examination I & FBT L [s] NT Examination II	30	85.50	3.02	0.002*
FBT R [s] T Examination I & FBT R [s] T Examination II	30	200.00	0.67	0.504 NS
FBT R [s] NT Examination I & FBT R [s] NT Examination II	30	127.00	2.17	0.030*

**p* ≤ 0.05; NS – not statistically significant

The comparative analysis of the values of the variables achieved in the I and II examination using dependent samples t-test did not show any statistically significant differences in either T or NT girls (Table 5). The difference in Y-POST-MED R in the T group was closest to the significance level at p≤0.05 – the calculated P-value was 0.086.

Table 5. Comparative analysis of the results of the first and second examination using the dependent samples t-test.

	Variables	Dependent samples t-test						
		$\bar{x}$	SD	N	Difference	*t*	*df*	*p*
T	Y-ANT L [%] Examination I Y-ANT L [%] Examination II	73.53 72.36	7.56 9.44	30	1.17	1.23	29	0.230 NS
T	Y-POST-MED L [%] Examination I Y-POST-MED L [%] Examination II	93.55 94.40	10.61 9.09	30	-0.85	-0.52	29	0.607 NS
T	Y-POST-LAT L [%] Examination I Y-POST-LAT L [%] Examination II	100.65 100.36	7.64 8.48	30	0.28	0.29	29	0.776 NS
T	Y-CS L [%] Examination I Y-CS L [%] Examination II	90.14 90.60	6.42 6.21	30	-0.46	-1.03	29	0.312 NS
T	Y-POST-MED R [%] Examination I Y-POST-MED R [%] Examination II	98.54 99.81	7.82 6.90	30	-1.27	-1.78	29	0.086 NS
T	Y-POST-LAT R [%] Examination I Y-POST-LAT R [%] Examination II	95.66 95.82	10.70 9.86	30	-0.15	-0.1	29	0.921 NS
NT	Y-ANT L [%] Examination I Y-ANT L [%] Examination II	72.84 72.20	6.68 5.39	30	0,65	0.64	29	0.527 NS
NT	Y-POST-MED L [%] Examination I Y-POST-MED L [%] Examination II	97.50 98.63	8.33 9.27	30	-1.14	-1.31	29	0.202 NS
NT	Y-POST-LAT L [%] Examination I Y-POST-LAT L [%] Examination II	100.08 100.98	8.20 7.43	30	-0.90	-1.21	29	0.236 NS
NT	Y-CS L [%] Examination I Y-CS L [%] Examination II	89.24 89.04	7.49 7.93	30	0.20	0.22	29	0.825 NS
NT	Y-POST-MED R [%] Examination I Y-POST-MED R [%] Examination II	97.58 95.89	8.26 8.27	0	1.69	1.41	29	0.169 NS
NT	Y-POST-LAT R [%] Examination I Y-POST-LAT R [%] Examination II	97.34 98.47	10.00 9.18	30	-1.13	-1.29	29	.206 NS

**p* ≤ 0.05; NS – statistically non-significant

Table 6 shows the intergroup comparative results in the first and second examination of Y-ANT R, Y-CS R, FBT L and FBT R. There is no statistical difference between the T and NT groups, both in examination I and in examination II, for any of the cases mentioned above.

Table 6. Intergroup analysis of the T and NT groups in the first and second examination using the non-parametric U Mann-Whitney pair compatibility test for independent samples.

Variables	T	NT	U	Z	*p*
Y-ANT R [%] Examination I	936.00	894.00	429.00	0.30	0.762 NS
Y-ANT R [%] Examination II	829.50	1000.50	364.50	-1.26	0.209 NS
Y-CS R [%] Examination I	963.00	867.00	402.00	0.70	0.483 NS
Y-CS R (%) Examination II	1033.50	796.00	331.50	1.75	0.081 NS
FBT L [s] Examination I	810.00	1020.00	345.00	-1.55	0.122 NS
FBT L [s] Examination II	976.00	854.00	389.00	0.89	0.371 NS
FBT R [s] Examination I	828.00	1002.00	363.00	-1.28	0.201 NS
FBT R [s] Examination II	964.00	866.00	401.00	0.72	0.473 NS

* $p \le 0.05$; NS – not statistically significant

Table 7 shows the results of intergroup comparative analysis of the studied variables in the first and second examination obtained with the use of the t-test for independent samples. No statistically significant difference was found between groups T and NT, either in examination I or in examination II, in dynamic balance measured with the YBT test. Only the difference between the means of both groups in examination II for Y-POST-MED R was close to the level of statistical significance (p = 0.051).

Table 7. Intergroup analysis of the T and NT groups in the first and second examination using the t-test of means for independent samples

Variables	Independent samples t-test													
	Examination I							Examination II						
	$\bar{x}$	SD	N	Difference	*t*	*df*	*p*	$\bar{x}$	SD	N	Difference	*t*	*df*	*p*
Y-ANT L [%] T	73.53	7.56	30	0.69	0.37	58	0.710	72.36	9.44	30	0.16	0.08	58	0.933
Y-ANT L [%] NT	72.84	6.68					NS	72.20	5.39					NS
Y-POST-MED L [%] T	93.55	10.61	30	3.95	-1.60	58	0.115	94.40	9.09	30	4.23	-1.78	58	0.080
Y-POST-MED L [%] NT	97.50	8.33					NS	98.63	9.27					NS
Y-POST-LAT L [%] T	100.65	7.64	30	0.57	0.28	58	0.781	100.36	8.48	30	0.62	-0.30	58	0.765
Y-POST-LAT L [%] NT	100.08	8.20					NS	100.98	7.43					NS
Y-CS L [%] T	90.15	6.42	30	0.90	0.50	58	0.621	90.60	6.21	30	1.56	0.85	58	0.400
Y-CS L [%] NT	89.24	7.49					NS	89.04	7.93					NS
Y-POST-MED R [%] T	98.54	7.82	30	0.96	0.46	58	0.648	99.81	6.90	30	3.92	1.99	58	0.051
Y-POST-MED R [%] NT	97.58	8.26					NS	95.89	8.27					NS
Y-POST-LAT R [%] T	95.66	10.70	30	1.68	-0.63	58	0.534	95.82	9.86	30	2.65	-1.08	58	0.285
Y-POST-LAT R [%] NT	97.34	10.00					NS	98.47	9.18					NS

Table 8 compares global YBT (Y-CS) scores with the Butler's postural stability index [6] in groups T and NT, respectively, calculated for both limbs after the first examination.

Table 8. Summary of global YBT scores in groups T and NT in the first examination

	Examination I T				Examination I NT			
No.	Y-CS R [%]	RESULT	Y-CS L [%]	RESULT	Y-CS R [%]	RESULT	Y-CS L [%]	RESULT
1.	92.66	1	93.45	1	96.74	1	95.21	1
2.	71.98	0	78.39	0	87.96	0	88.70	0
3.	83.73	0	88.10	0	83.13	0	88.48	0
4.	89.44	0	95.00	1	87.73	0	83.88	0
5.	89.27	0	95.02	1	79.12	0	78.02	0
6.	85.06	0	88.51	0	80.37	0	87.59	0
7.	87.65	0	85.69	0	103.75	1	104.17	1
8.	85.90	0	86.81	0	96.74	1	96.36	1
9.	92.59	1	95.74	1	87.28	0	83.87	0
10.	87.95	0	92.17	1	99.23	1	96.17	1
11.	75.42	0	77.50	0	80.46	0	81.61	0
12.	93.46	1	95.36	1	93.30	1	95.11	1
13.	91.96	1	90.78	1	81.18	0	80.78	0
14.	87.27	0	90.07	1	79.63	0	82.59	0
15.	91.21	1	85.53	0	78.79	0	80.98	0
16.	82.38	0	83.14	0	84.24	0	89.13	0
17.	80.78	0	85.49	0	103.09	1	105.56	1
18.	82.98	0	78.60	0	95.58	1	95.58	1
19.	111.11	1	103.37	1	92.03	1	92.39	1
20.	94.78	1	94.78	1	81.27	0	74.23	0
21.	95.16	1	87.60	0	104.07	1	101.55	1
22.	92.55	1	89.41	0	85.46	0	89.18	0
23.	92.21	1	93.07	1	80.80	0	84.96	0
24.	98.84	1	101.94	1	87.60	0	90.70	1
25.	97.67	1	89.15	0	92.53	1	93.87	1
26.	84.92	0	97.22	1	85.19	0	83.70	0
27.	78.41	0	85.61	0	82.77	0	86.89	0
28.	97.25	1	85.69	0	89.20	0	90.53	1
29.	93.92	1	92.94	1	85.61	0	83.90	0
30.	88.76	0	97.99	1	89.96	1	91.57	1
	SUM 1	14 [46.7%]	SUM 1	15 [50%]	SUM 1	11 [36.7%]	SUM 1	13 [43.3%]
	SUM 0	16 [53.3%]	SUM 0	15 [50%]	SUM 0	19 [63.3%]	SUM 0	17 [56.7%]

In group T, 14 girls exceeded the limit of the index for the right limb and 15 girls exceeded it for the left limb (rank '1'). The number of the girls with rank '0' was 16 for the right limb and 15 for the left one. In the NT group, however, 11girls exceeded the index limit for the right limb and 13 for the left one (rank '1'). Furthermore, the number of the girls with rank '0' was 19 for the right lower limb and 17 for the left one.

Table 9 shows the global scores of the Y-Balance Test (Y-CS) with postural stability index of girls T and NT calculated after the second examination.

Table 9. Summary of global YBT scores in groups T and NT in the second examination

	Examination II T				Examination II NT			
No.	Y-CS R [%]	RESULT	Y-CS L [%]	RESULT	Y-CS R [%]	RESULT	Y-CS L [%]	RESULT
1.	93.65	1	94.25	1	91.00	1	92.53	1
2.	81.14	0	80.22	0	88.33	0	89.81	1
3.	85.91	0	90.28	1	84.98	0	90.74	1
4.	89.07	0	96.11	1	80.77	0	81.14	0
5.	92.72	1	90.61	1	71.61	0	73.08	0
6.	91.00	1	83.33	0	86.11	0	90.19	1
7.	88.04	0	85.49	0	104.17	1	106.88	1
8.	85.53	0	86.45	0	97.70	1	96.74	1
9.	92.59	1	95.56	1	82.08	0	84.59	0
10.	87.15	0	92.77	1	98.85	1	99.62	1
11.	75.83	0	77.92	0	81.61	0	78.93	0
12.	93.67	1	100.00	1	95.47	1	96.92	1
13.	90.39	1	88.63	0	76.08	0	86.27	0
14.	88.95	0	91.01	1	80.19	0	83.70	0
15.	84.80	0	87.91	0	85.86	0	81.48	0
16.	90.04	1	86.21	0	86.23	0	90.76	1
17.	81.57	0	83.14	0	93.00	1	94.65	1
18.	85.61	0	79.65	0	85.54	0	89.36	0
19.	103.97	1	97.62	1	83.33	0	91.30	1
20.	90.96	1	96.99	1	89.18	0	86.25	0
21.	90.50	1	91.09	1	102.91	1	107.36	1
22.	93.73	1	91.96	1	89.89	1	93.62	1
23.	94.81	1	93.29	1	87.68	0	84.42	0
24.	100.00	1	100.78	1	88.95	0	91.47	1
25.	98.06	1	89.92	1	88.89	0	84.67	0
26.	86.51	0	98.41	1	78.15	0	88.15	0
27.	79.55	0	86.17	0	89.14	0	84.46	0
28.	98.63	1	87.65	0	85.61	0	87.12	0
29.	93.33	1	96.67	1	72.35	0	73.48	0
30.	89.36	0	97.99	1	88.76	0	91.57	1
	SUM 1	16 [53.3%]	SUM 1	18 [60%]	SUM 1	8 (26.7%)	SUM 1	15 (50%)
	SUM 0	14 [46.7%]	SUM 0	12 [40%]	SUM 0	22 (73.3%)	SUM 0	15 (50%)

In group T, 16 girls exceeded the limit of the index for the right limb, whereas 18 girls exceeded it for the left limb (rank '1'). The number of the girls with rank '0' was 14 for the right limb and 12 for the left one. In group NT, however, 8 girls exceeded the limit of the index for the right limb and 15 girls exceeded it for the left limb (rank '1'). The number of the girls with rank '0' in this group was 22 for the right lower limb and 15 for the left one.

4. Discussion

The study shows that volleyball training differently affects the level of static and dynamic balance in the examined girls. The girls from the NT group, somehow surprisingly, showed slightly better static postural stability than girls in the T group. In this respect, a significant improvement in both limbs was noted in the NT group in the second examination. In group T, a significant improvement was noted only for the left lower limb. In group T, the measured mean FBT index in the first examination for the left lower limb was 9.07 s, while in the second one 12.45 s – the recorded increase reached 27%. For the right lower limb, the FBT value in the first examination was 10.54 s, and in the second one 11.88 s – in this case, the increase of 13% was twice lower than that for the left limb. In the NT group, similar increases in the FBT index were noted for the left and right lower limbs (by 18% and 19%, respectively). Almost the same positive results in 14- and 15-year-old female volleyball players of different skill levels were obtained with the use of FBT by Klocek and Żak [15].

A comparative analysis of the results of the first and the second YBT examinations in group T showed that there was a significant difference (p = 0.025) only between the Y-ANT R values – the percentage difference was almost 4%. In the second examination, an intergroup difference of almost 4% in the Y-POST-MED R value range was found. The mean value of this shift for the T girls was 99.81% and for the NT girls 95.87%. The observed difference was close to the level of statistical significance (p = 0.051). Our results are to some extent consistent with the results of other authors, which proves that volleyball training can positively affect postural stability. Many studies show that the improvement in stability is associated with the improved attack and the effectiveness in defense, as well as with a reduced risk of injury among female volleyball players. Improvement in coordination skills in young athletes may be a decisive factor in entering an elite high level senior competition [16].

Paz et al. [17] have observed that there were significant differences in agility and speed between female volleyball players occupying different positions on the field; However, there were no differences in power, strength and dynamic balance measured by the 'star' test (SEBT, a prototype of the YBT). Therefore, they suggest that these results be used to determine the somatic-motor profile of players performing different field position-related tasks and to plan training programs to optimize the level of selected motor skills, especially coordination skills. Adiguzel and Koc [18], using the SEBT, compared young female volleyball players with their peers playing football. The football players achieved significantly better results for two directions for the right limb (posterolateral and medial) and for two directions for the left limb (medial and posterior). However, the volleyball players did not show better results for any direction. A study by Pau et al. [19] evaluated the effect of a 6-week balance training (BT) added to regular traditional training sessions on postural stability of 13-year-old female volleyball players divided into study and control groups. The study participants were subjected to balance tests carried out in bilateral and unilateral stance before and after the BT intervention on a stabilographic platform. In the group that had additional BT, smaller areas of oscillation of the center of gravity in the bilateral stance test with closed eyes were found, as well as a reduction in the area of antero-posterior COP displacement in the stance on the non-dominant limb was observed. There was no significant change for the dominant limb. Based on the above, a hypothesis can be made that volleyball training with extra balance training elements has a favorable effect on young female volleyball players.

Similar conclusions were drawn in a study conducted by Devrim and Erdem [20], who tested 45 female volleyball players aged 12 at an 8-week interval, with the FBT test, among others. The control group included girls participating in typical volleyball training, the other 2 groups were experimental, and they had additional elements (I – plyometric training, II – fast strength training) apart from their routine training. The first examination did not show any significant differences between the study groups. After 8 weeks, the group with added plyometric training significantly improved their results (improvement in FBT was at a significance level of $p < 0.01$, and it was 1.8 s on average). Similar results were obtained in the group with fast strength training, and there was a significant improvement in FBT by an average of 1.6 s. The authors concluded that plyometric training and strength training could have a positive impact on static balance improvement and it is worth integrating it into the process of volleyball training.

Guirelli et al. [21] studied 25 female volleyball players aged 15. They were interested in the relationship between muscle strength measured with a dynamometer and postural stability measured by the YBT test. Their study showed a statistically significant correlation between the strength of the knee extensors and the result of marker movement in the anterior direction in the YBT. A similar relationship was shown for hip extensors and posterolateral reach. In their conclusions, the authors suggested identification of weak points during YBT testing followed by targeted workout of specific muscle groups to improve the stability of the lower limbs and thus prevent injuries among young female volleyball players.

Similarly, a study by Boguszewski et al. [22] points to the need for stabilization training within basic volleyball training. The researchers assessed two groups of female volleyball players aged 14, using the FMS test to assess function (including stabilization) and to determine the risk of injury resulting from physical activity. All subjects had a typical volleyball training session 3 times per week, and the experimental group additionally had exercises improving stability. After a 2-month training program, significant differences were observed: the girls in the experimental group improved their mean global score from 11.5 to 14.56 points with no significant differences in the control group. The researchers concluded that posture stabilization training is an important element of injury prevention and allows for significant increases in the FMS test results.

Hammami et al. [23] believe that working on postural stability is one of the elements that allow improving other motor skills and thus reducing the risk of injury. Eleven female volleyball players aged 14 were classified into 3 groups; after a standard warm-up, each of them was examined on a dynamometer platform for static stability. Then all the groups underwent balance and stabilization training according to 3 different protocols. Each of them consisted of 15-minute exercises on an unstable surface: the first group performed one-leg stance exercises in the sagittal plane, the second group followed frontal plane patterns, and the third one performed rotational movements. Immediately after they had completed the exercises, each of the subjects was examined in the same way as after the warm-up. The results did not show any statistically significant inter-group differences. However, there was a trend for improvement in the surface area of the center of pressure on the base in each group. The authors suggested that balance exercises on unstable surfaces should be included on a regular basis in training units of young female volleyball players.

Some researchers suggest that also factors other than sports improve postural stability during adolescence. Paniccia et al. [24] demonstrated significant effect of age and sex on postural stability in children aged 9 to 12. Stability improved with age, and girls performed better than boys. This is also confirmed by the results of a study by Devrim and Erdem [20], who examined 12-year-old (2 years younger) female volleyball players using FBT and their mean results were significantly worse than these obtained in our study. What is also important in the context of our considerations is that stability also gradually improved between the age of 13 and 18, provided that there were no injuries. This fact can probably explain the improvement in postural stability also in the NT girls examined in our study.

In their study examining coordination abilities of young female volleyball players, Boichuk et al. [25] place postural stability in the high third position in their factor analysis in the context of its training-related impact on sports performance achieved in the sub-period of special preparation. Among other coordination abilities that influence the formation of technical and tactical skills, the only ones which they put higher in classification are the ability of fast movement coordination and kinesthetic differentiation and the ability to quickly reproduce motor activities. Surprisingly, in the last – fifth – place they list the reaction ability. Therefore, it seems appropriate to improve these specific coordination skills of female volleyball players through properly targeted training measures. The report of Zadorozhna [26] demonstrates that high athletic performance can only be achieved by reliable assessment of dynamic, spatial, and temporal coordination parameters and their regulation when dosing training.

The lack of clear differences between the results of the first and second examination in both groups of girls, in particular in the area of dynamic balance, can be most likely explained by the subjects' age, both in our and in other studies. In the majority of tests, the observed stabilization of motor coordination in girls at the age of 12–14 is caused by significant adolescence-related morphological and functional changes [27]. This is particularly evident in their ability to control ballistic and sporting movements [28]. According to Mraz et al. [2] and Kostiukow et al. [29] the above-mentioned period is described as critical for balance-related behavior, as it is characterized by temporary stagnation and even partial regression.

In order to better illustrate the difference in YBT scores between the T and NT girls in both the first and the second examinations, the global test scores (Y-CS) were compared to the index setting the limit between better and worse postural stability [5] (Tables 8 and 9). In the first examination, girls T exceeded the index limit by 46.7% for the right lower limb and by 50% for the left one (Table 8). An improvement was noted in the second examination: for the right limb the index was exceeded by 53.3%, and for the left one by 60% (Table 9). In the NT group, 36.7% of girls exceeded the limit of the index for the right limb, and 43.3% of girls exceeded it for the left limb in the first examination (Table 8), while in the second examination these values were 26.7% for the right limb (worsening) and 50% for the left limb – a clear positive progression (Table 9). To summarize, in girls from group T the risk of injury for both lower limbs was significantly reduced, whereas in the case of group NT this was true only for the left limb. Paradoxically, the risk increased (by about 10%) for the right limb. It is difficult to find a rational explanation for this fact.

Proper recruitment and selection are the basic factors determining the effectiveness of training in sport. Many authors believe that the main criterion of selection of volleyball players should be the body height, pointing to its relationship with sports achievements, as well as with the level of effectiveness of individual elements of the technique. Of course, the level of physical fitness is also an important factor. In disciplines which are characterized by high complexity of movements and the need for ability to adapt to changing conditions, the level of motor coordination is the decisive factor in the outcome of competition [30, 31].

Based on the conducted study and the literature review, it can be concluded that volleyball training has a generally favorable effect on the level of static and dynamic balance. Additionally, a positive effect of standard physical education classes on the level of static balance in NT girls can be observed. It should also be noted that the results obtained by the authors of this work are limited to a specific age and sex group, as well as to specific tests of postural stability. In other words, the results of this study cannot be generalized to the entire population, or to any other type of sports activity or postural stability tests. It is also worth noting that this work does not take into consideration some factors related to volleyball training, such as intensity, frequency, or duration of training sessions, which may affect postural stability. The results of this study may have significant implications for coaches and professionals dealing with athletes' health and recovery who need to consider postural stability during the training process. Therefore, the authors of this work suggest that, for injury prevention, it is worth including in both volleyball training and in physical education classes in schools additional exercises based on coordination skills and balance abilities.

5. Conclusions

Comparative analysis of postural stability measured under static conditions between the first (I) and the second (II) examination revealed some statistically significant differences in FBT L in girls T and in FBT L and FBT R in girls NT. Three months of volleyball training significantly affected changes in only one of the dynamic balance indicators – Y-ANT R in the T girls. For the other YBT measurements, in both T and NT girls, the changes were not statistically significant. Both in the first and the second examination, there were no statistically significant differences in the intergroup YBT values. The largest difference (4%) was recorded for the Y-POST-MED R reach in the second examination. The mean value of this shift in group T was 99.81% and in group NT – 95.87%. The observed difference was close to the level of statistical significance. In group T in the second examination, 53.3% of the subjects exceeded the limit of the global YBT score for the right lower limb and 60% for the left lower limb. As compared to the first examination, this was an increase of 6.6% and 10% for the right and left lower limb, respectively. In group NT in the second examination, 26.7% of the subjects exceeded the limit of the global YBT index for the right lower limb and 50% for the left lower limb. As compared to the first examination, this was a 10% decrease for the right lower limb and a 6.7% increase for the left lower limb.

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