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Impact of VO2max on mechanical variables, lactic acid concentration and shooting accuracy of the 7-meter throw among handball players

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ABSTRACT

The aim of this study was to determine the effect of various VO2 max rates on mechanical variables, lactic acid concentration, and shooting accuracy of the 7-meter throw among handball players. The experimental method consisted of two experiments: one for calculating the VO2 max in the laboratory and another for testing the shooting accuracy of the 7-meter throw. A total of 36 handball players who specialized in shooting the 7-meter throw participated in the current study. They were divided into three equal groups in terms of training age, VO2 max level and the shooting accuracy of the 7-meter throw at rest time. Their average age was 24.1±3.2 years, their height was 177±23 cm, and their weight was 72±4.3 kg. We used three Canon Eos 80D cameras, a Scout Cortex lactate device, and Kinovea 0.9.5 software for performance evaluation. The study's results revealed a statistically significant effect of multiple rates of VO2 max on some mechanical variables, lactic acid concentration, and shooting accuracy of the 7-meter throw among handball players, with a negative effect that increases when the rates of VO2 max become greater at the level of significance (α = 0.00). In light of the study's results, the researcher advised handball coaches to work on increasing their players' VO2 max levels or delaying their players' access to higher levels of VO2 max to avoid an increase in the concentration of lactic acid in the blood and, as a result, a decrease in the players' abilities to perform the 7-meter throw skill. According to the results of this study, they should also consider the use of pauses and substitutions during matches to ensure that players do not reach levels of up to 65% of VO2 max.

KEYWORDS

VO2 max; Kinematic Variables; 7-Meter Throw; Handball; Shooting Accuracy

1. INTRODUCTION

Energy production via the aerobic system is crucial for success in all types of sports, including those with an anaerobic component, such as team sports like football, handball, and basketball, which have a common system that combines the aerobic and anaerobic systems (Birch, 2005).

The maximum oxygen production (VO2 max) is one of the most important measures that determine the performance intensity of aerobic activity and the ability of the respiratory circulatory system to provide sufficient oxygen to sustain energy production within the mitochondria in the muscles. VO2 max is the best indicator of an individual's aerobic capacity (Živanić et al., 1999).

In fact, the value of VO2 max is a maximum value that cannot be increased instantly during competition, necessitating the development of training programs to raise it and increase the players' benefit from their aerobic abilities. The maximum oxygen consumption can be expressed in two values, either a relative value and a unit of measurement in ml/kg/min, or as an absolute value and a unit of measurement in L/min. VO2 max can be calculated directly through gas analysis or through multiple equations (Buttar et al., 2019). In all cases, a higher VO2 max level is the trump card for the athlete that sets him or her apart from others, even in sports with a joint energy system between aerobic and anaerobic, such as handball (Bassett & Howley, 2000).

Despite the fact that handball is a sport based on transitions between defense and attack and is characterized by quick high-intensity skills performed anaerobically, the aerobic system is an important part of the energy production of the handball player, who runs a distance of 4-6 km during one match. For example, the player in the handball game performs anaerobic skills within the range of aerobic energy production, where the percentage of performance intensity exceeds 80% of the VO2 max. Therefore, there is an unavoidable link between a handball player's ability to perform game skills and their aerobic ability, indicated by the VO2 max (Bassett & Howley, 2000).

According to a study by Milenković. et al. (2013), handball players can achieve a VO2 max of 51.90 ml/kg/min, while Vargas et al. (2008) show that handball players can achieve 45.30 ml/kg/min. Zapartidis et al. (2009) demonstrated that handball players can achieve VO2 max of 50.41 ml/kg/min, and these results represent significant values in the physiology of sports training and the convergence of some sports with aerobic energy systems (Wilmore & Costill, 2015).

In terms of lactic acid, the handball game combines aerobic and anaerobic energy systems due to the long playing time, which is an hour of uninterrupted play, and a transition to handball skills that are performed quickly with high intensity. These conditions increase the likelihood of lactic acid

concentration in the blood, and the effect of this increase is visible when performing skills that require speed and strength, such as shooting the ball into the goal (Belcic et al., 2021). The physiological demands of handball, which are based on the aerobic and anaerobic systems, contribute significantly to an increase in lactic acid concentration in the blood (Chaouachi, 2009). It should be noted that reaching 50% of VO2 max means the start of lactic acid formation and an increase in its concentration in athletes' blood (Wilmore & Costill, 2015).

On the other hand, scoring a goal is the most visible objective and criterion of success in handball. The 7-meter throw that can be executed from movement or stability appears to be the greatest scoring opportunity in this game, and the team players' possession of the shooting accuracy of this throw constitutes a success factor that increases the team's chances of winning the match. It is a skill that requires precise execution and is affected by several mechanical factors, such as the angular velocities of the shoulder joint, the extension of the elbow joint, and the ball velocity (Wagner et al., 2009). In order to ensure the success of his/her skill performance when performing different types of shooting, the handball player must develop a mechanical model that includes the angles of the upper limb (Tillar & Ettema, 2007).

The idea for this study came from the preceding, which sought to determine the effect of differences in the VO2 max rate on mechanical variables related to the accuracy of the 7-meter throw of stability among handball players, as any influence on skill performance is related to changes in the mechanics of this performance, resulting in skillful achievement (Skejø et al., 2019). This study also sought to determine the percentage of VO2 max at which the concentration of lactic acid in the blood begins to approach 2 mmol, known as the first anaerobic threshold, and the percentage of VO2 max at which the concentration of lactic acid in the blood exceeds 4 mmol, known as the second anaerobic threshold (Wilmore & Costill, 2015), We also tried to determine the impact of all of this on the shooting accuracy of the 7-meter throw from stability and set a percentage of 50% as a minimum, since this is the percentage at which the concentration of lactic acid begins to reach the anaerobic threshold, then the increase was increased by 15% to reach 65%, then 80% of VO2 max. It was stated that handball players reach approximately 80% of their VO2 max during matches (Buchheit, 2014).

The hypothesis of the study was that multiple rates of VO2 max would have a statistically significant effect on some mechanical variables, lactic acid concentration, and 7-meter throw accuracy in handball players.

2. METHODS

2.1. Study Design and Participants

In this experimental study, 36 handball players who specialize in shooting penalty throws were divided into three equal groups based on training age, VO2 max level, and shooting accuracy of the 7-meter throw at rest time. Table 1 shows the equivalence result.

Table 1. The equivalence of the three groups in the variables of training age, maximum oxygen consumption, and shooting accuracy of the 7-meter throw

Variables	Group	Means		Kruskal–Wallis Test				
		Mean	SD	Total Ranks	No.	Average Ranks	X^2 value	p value
Training Age (Year)	First Experimental 50%	6.96	1.36	222	12	18.50	0.151	0.927
	Second Experimental 65%	7.08	0.89	212	12	17.67		
	Third Experimental 80%	7.25	0.74	232	12	19.33		
Oxygen Consumption (ml/min)	First Experimental 50%	43.82	2.31	210.5	12	17.54	0.157	0.925
	Second Experimental 65%	43.94	2.18	230	12	19.17		
	Third Experimental 80%	44.22	2.61	225.5	12	18.79		
Accuracy of the 7-Meter Throw (Score of 10)	First Experimental 50%	8.17	0.83	218.5	12	18.21	0.063	0.969
	Second Experimental 65%	8.17	0.83	218.5	12	18.21		
	Third Experimental 80%	8.25	0.75	229	12	19.08		

As we can see from the Kruskal's test results, we have a p value of 0.927 for the first variable (training age), a p value of 0.925 for the second variable (oxygen consumption) and for the third variable (accuracy of the 7-meter throw), we have a p value of 0.969. These values show us that the three groups are equal in these variables.

2.2. Study Tests

- Test name: Accuracy of the 7-meter handball throw.
- Test purpose: Measuring the accuracy of the 7-meter handball throw.
- Equipment required: 10 men's handballs (size 3), a curtain covers the goal and has a circle with a diameter of 60 cm in its upper corner, a scorer, a legal handball goal, a legal handball (Figure 1).

- Implementation method: The player stands directly behind the 7-meter throw line and shoots from stability towards the circle, causing the ball to enter the circle and travel beyond the curtain that covers it, where the player makes 10 throws.
- Points Calculation: points are given as follows:

1. A ball that enters the circle receives 1 point.
2. A ball that does not enter the circle receives no points.

Figure 1. The image of the goal and curtain in the study test

2.3. Study Procedures

- Calculating the participants' VO2 max levels using a maximum oxygen consumption test based on gas analysis.
- Conducting a 7-meter throw accuracy test for the participants at rest time.
- Dividing the participants into three groups based on statistical equivalence.
- After 72 hours, repeating the VO2 max test for the participants until each participant reaches the required percentage of VO2 max according to his group. The first group participants are stopped when they reach 50% of VO2 max, the second group participants are stopped when they reach 65% of VO2 max, and the third group participants are stopped when they reach 80% of VO2 max.
- Immediately after the VO2 max test, the participant's blood lactic acid concentration is calculated by pricking the participant's earlobe and inserting the sample into the Scout Cortex lactate device.
- The participant is asked to perform a 7-meter throw precision test.

- Filming the 7-meter throw test with three cameras distributed on the lateral, front, and vertical performance axes, all of which are Canon EOS 80 D cameras with a frame rate of 500 images per second.
- Analyzing videos to extract mechanical variables, using Kinovea 0.9.5 for kinetic analysis.

2.4. Data Analysis

The search data was processed through the Statistical Package for the Social Sciences (SPSS). The Kruskal-Wallis nonparametric test was used to investigate differences in mechanical variables between the three groups, while the least significant difference (LSD) test was used to determine to determine if there is a statistically significant difference in the mean scores of the experimental groups on the mechanical variables.

3. RESULTS

We begin the presentation of the results by showing and explaining the differences in mechanical variables between the study groups.

Table 2. The differences in the mechanical variables between the study groups

Variables	Group	Arithmetic Means		Kruskal–Wallis Test				
		Mean	SD	Total Ranks	No.	Average Ranks	X^2 value	p value
Ball Velocity	First Experimental 50%	19.50	1.45	365.5	12	30.46	30.53	0.000*
	Second Experimental 65%	15.08	1.16	219	12	18.25		
	Third Experimental 80%	11.92	1.08	81.5	12	6.79		
Angular Velocity of the Trunk's Forward Tilt	First Experimental 50%	186.75	3.96	360	12	30.00	29.95	0.000*
	Second Experimental 65%	165.92	9.77	228	12	19.00		
	Third Experimental 80%	125.25	4.22	78	12	6.50		
Angular Velocity of Inward Shoulder Rotation	First Experimental 50%	3907.42	104.07	366	12	30.50	29.04	0.000*
	Second Experimental 65%	3030.00	171.44	211.5	12	17.63		
	Third Experimental 80%	2320.17	371.96	88.5	12	7.38		
Angular Velocity of Elbow Extension	First Experimental 50%	1604.00	62.47	365	12	30.42	26.84	0.000*
	Second Experimental 65%	1316.67	128.28	201	12	16.75		
	Third Experimental 80%	1158.00	108.60	100	12	8.33		

** Statistically significant differences at the significance level of 0.05 or less*

From Table 2 we notice that for all variables presented in the table, we have a p value of 0.000 which indicates statistically significant differences in the mechanical variables between the study groups.

Next, we use the least significant difference (LSD) test to determine if there is a statistically significant difference in the mean scores of the experimental groups on the mechanical variables (Table 3).

Table 3. The difference in the mean scores of the experimental groups on the mechanical variables

Mechanical Variables	Mean	Groups	Second Experimental Groups 65%	Third Experimental Groups 80%
Ball Velocity	19.50	First Experimental Groups 50%	*	*
	15.08	Second Experimental Groups 65%	-	*
	11.92	Third Experimental Groups 80%		-
Angular Velocity of the Trunk's Forward Tilt	186.75	First Experimental Groups 50%	*	*
	165.92	Second Experimental Groups 65%	-	*
	125.25	Third Experimental Groups 80%		-
Angular Velocity of Inward Shoulder Rotation	3907.42	First Experimental Groups 50%	*	*
	3030.00	Second Experimental Groups 65%	-	*
	2320.17	Third Experimental Groups 80%		-
Angular Velocity of Elbow Extension	1604.00	First Experimental Groups 50%	*	*
	1316.67	Second Experimental Groups 65%	-	*
	1158.00	Third Experimental Groups 80%		-

* *Statistically significant differences at the significance level of 0.05 or less*

In all the four mechanical variables, the differences were between the first experimental group and the second experimental group, so that the difference was statistically significant in favor of the first experimental group (50%), depending on the arithmetic mean values that were greater for this group compared to the second experimental group which worked with 65% of the maximum oxygen consumption. There were also differences between the first experimental group and the third experimental group, in favor of the first experimental group, and between the second experimental group and the third experimental group, in favor of the second experimental group.

The following table (Table 4) shows the differences between the three groups in the two variables of the accuracy of the 7-meter throw and the lactic acid.

By reviewing the values of the significance level of Kruskal's test for the 7-meter throw accuracy variable (a score of 10), it is clear that we have statistically significant differences between the three groups ($p < 0.05$).

Table 4. The differences between the three groups in the variables of the accuracy of 7-meter throw and lactic acid.

Variables	Group	Mean	SD	Kruskal-Wallis Test				
				Total Rank	No.	Average Ranks	X^2 Value	p value
Accuracy of the 7-Meter Throw (Score of 10)	First Experimental Groups 50%	7.92	0.79	364	12	30.33	30.76	*0.000
	Second Experimental Groups 65%	5.42	0.79	222	12	18.50		
	Third Experimental Groups 80%	2.92	1.00	80	12	6.67		
Lactic Acid Concentration (mmol/L)	First Experimental Groups 50%	1.37	0.16	78	12	6.50	31.37	*0.000
	Second Experimental Groups 65%	2.43	0.33	222	12	18.50		
	Third Experimental Groups 80%	4.16	0.11	366	12	30.50		

**(statistically significant differences at the significance level of 0.05 or less)*

In order to determine the differences between groups whose arithmetic mean values differ significantly from a statistical point of view, the least significant difference test was used and the following table shows these results (Table 5).

Table 5. The experimental groups results whose averages are statistically different in the two variables (accuracy of the 7-meter throw and level of lactic acid concentration).

Variables	Arithmetic Mean	Group	Second Experimental Groups 65%	Third Experimental Groups 80%
Accuracy of the 7-Meter Throw	7.92	First Experimental Groups 50%	*	*
	5.42	Second Experimental Groups 65%	-	*
	2.92	Third Experimental Groups 80%		-
Lactic Acid Concentration	1.37	First Experimental Groups 50%	*	*
	2.43	Second Experimental Groups 65%	-	*
	4.16	Third Experimental Groups 80%		-

**(statistically significant differences at the significance level of 0.05 or less)*

- The accuracy of the 7-meter throw

Regarding the first variable, there were differences between the first experimental group and the second experimental group, in favor of the first experimental group (50%), and there were also differences between the first experimental group and the third experimental group, in favor of the first experimental group. In addition, differences were found between the second experimental group and the third experimental group, in favor of the second experimental group.

- Lactic Acid Concentration Level

Regarding the second variable, we have differences between the first experimental group and the second experimental group, in favor of the first experimental group. We also have differences

between the first experimental group and the third experimental group, in favor of the first experimental group, and between the second experimental group and the third experimental group, in favor of the second experimental group.

4. DISCUSSION

The findings of our study demonstrated that raising the VO2 max rate, which increased the participants' performance intensity, had a statistically significant impact on all mechanical and physiological study variables ($p < 0.05$), such as the concentration of lactic acid in the blood or the accuracy of handball players' 7-meter throw. This suggests that handball players lose a significant portion of their technical and skill abilities when working in highly specialized circumstances, notably when shooting the 7-meter throw. Therefore Zapartidis et al. (2015) pointed out the need for the coach to take into account the intermittent periods during the handball match and to give the players sufficient rest during the performance to avoid reaching a high level of VO2 max, especially in matches that require a high-intensity performance. This is confirmed by Wilmore & Costill (2015), as they indicate that continuous progress in performance leads to an increase in the concentration of lactic acid in the blood and a decrease in physical and skill performance.

Looking at the results, we find that the first experimental group was the best in terms of achieving the mechanical goal, which measures the achievement of the skill dealt with in this study, which is the accuracy of the 7-meter throw. Indeed, this preference came as a logical outcome based on the kinematic variables and was associated with a decrease in the concentration of lactic acid in the blood, which reached in the first group (1.37 mmol), meaning that it did not reach the first anaerobic threshold, which is approximately 2 mmol. Moreover, looking at the mechanical variables of the first group, we find that the ball velocity, the angular velocity of the trunk's forward tilt, the angular velocity of elbow extension, and the angular velocity of inward shoulder rotation were higher values for all of these variables compared to the second experimental group, which worked under stress conditions that amounted to 65% of the VO2 max. Then, we found that the difference has increased at the first group if we compare it with the third experimental group that worked under severe conditions, which amounted to 80% of the VO2 max. Comparing the second and third groups, we find that the second group had higher mechanical variable values than the third group, indicating that angular and ball velocities decreased with increasing VO2 max intensity rates. This occurs as a result of the high intensity producing higher levels of lactic acid, which the higher the intensity, the higher its concentration in the blood, reaching an amount of (2.43) mmol in the second experimental group exceeding the first anaerobic threshold (4.16) mm in the third experimental group exceeding

the second anaerobic threshold (Wilmore & Costill, 2015). As each group's blood lactic acid concentration increased, the effectiveness of muscle work and the sliding of actin filaments onto myosin decreased, which in turn decreased the performance force and the angular velocities of the work done by the joints in the hitting hand. This decreased the kinetic transport that reaches the ball, which leads to a decrease in its speed and consequently its accuracy. This is consistent with studies by Nuno et al. (2016); Belcic et al. (2021), who indicated that muscle fatigue associated with an increase in the concentration of lactic acid in the blood affects the performance variables of mechanical shooting in handball players, while the accuracy of the shooting is the final result of mechanical performance. This is normal since the intensity has an impact on the mechanical factors, which in turn has an impact on accuracy. Indeed, we find that the accuracy of the first experimental group was 7,92, then it decreased to 5.42 in the second group, then it continued to decrease and reached 2.92 in the third group, and this matter shows the significant impact of the intensity height on the final achievement, which is the handball players' accuracy of the 7-meter throw.

The lactic acid concentration and the accuracy of shooting the 7-meter throw among handball players are two mechanical variables that are negatively impacted by multiple VO2 max ratios, an effect that becomes statistically significant as the rate of VO2 max increases. This finding supports the study's hypothesis.

5. CONCLUSIONS

When performing the 7-meter throw skill of stability, handball players are adversely affected by the high intensity of the competition in accordance with their level of VO2 max. This adverse effect grows as the percentage increases, especially when it exceeds the 65% barrier of VO2 max, so that the concentration of lactic acid in the blood increases and reaches the anaerobic threshold. Since there is an inverse relationship between the accuracy of the 7-meter throw and the height of intensity according to the ratios of the VO2 max, the mechanical model for performing this skill is disturbed, and the angular velocities drop as well as the ball speed and accuracy. This means that handball coaches should work to raise the level of VO2 max in their players or delay the players' access to higher levels of VO2 max to avoid an increase in the concentration of lactic acid in the blood and consequently a decrease in the players' abilities to perform the 7-meter throw skill. They should also take into account the use of pauses and substitutions during matches, in a way that ensures that players do not reach levels of up to 65% of VO2 max, according to the results of this study.

6. REFERENCES

1. Bassett, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise, 32*(1), 70-84. https://doi.org/10.1097/00005768-200001000-00012
2. Belcic, I., Rodić, S., Dukarić, V., Rupčić, T., & Knjaz, D. (2021). Do Blood Lactate Levels Affect the Kinematic Patterns of Jump Shots in Handball*? International Journal of Environmental Research and Public Health, 18*(20), 10809. https://doi.org/10.3390/ijerph182010809
3. Birch, K., MacLaren, D., & George, K. (2005). *Sport and exercise physiology*. Abington: BIOS Scientific Publishers.
4. Buchheit, M. (2014). Programming high-intensity training in handball. *Aspetar Sports Medicine Journal, 4*(3), 120-128.
5. Buttar, K. K., Saboo, N., & Kacker, S. (2019). A review: Maximal oxygen uptake (VO2 max) and its estimation methods. *International Journal of Physical Education, Sports and Health, 6*, 24-32.
6. Chaouachi, A., Brughelli, M., Levin, G., Boudhina, N. B. B., Cronin, J., & Chamari, K. (2009). Anthropometric, physiological and performance characteristics of elite team-handball players. *Journal of Sports Sciences, 27*(2), 151-157. https://doi.org/10.1080/02640410802448731
7. Milenković, V., Vitošević, B., Vidaković, H. M., Nedin, G. R., & Ranković, J. (2013). Values of aerobic capacity in handball and volleyball players. *Acta Medica Medianae, 52*(4), 35-38.
8. Nuño, A., Chirosa, I. J., Tillaar, V. R., Guisado, R., Martín, I., Martinez, I., & Chirosa, L. J. (2016). Effects of fatigue on throwing performance in experienced team handball players. *Journal of Human Kinetics, 54*(1), 103-113.
9. Skejø, S. D., Møller, M., Bencke, J., & Sørensen, H. (2019). Shoulder kinematics and kinetics of team handball throwing: A scoping review. *Human Movement Science, 64*, 203-212. https://doi.org/10.1016/j.humov.2019.02.006
10. Tillaar, V., & Ettema, G. (2007). A three-dimensional analysis of overarm throwing in experienced handball players. *Journal of Applied Biomechanics, 23*(1), 12-19. https://doi.org/10.1123/jab.23.1.12

11. Vargas, R. P., Dick, D. D., de Santi, H., Duarte, M., & da Cunha Júnior, A. T. (2008). Evaluation of physiological characteristics of female handball athletes. *Fitness & Performance Journal (Online Edition), 7*(2), 93-98.
12. Wagner, H., Buchecker, M., & Müller, E. (2009). Kinematic Analysis in Team-Handball Jump Throw. In *27th International Symposium on Biomechanics in Sports*, 757.
13. Zapartidis, I., Vareltzis, I., Gouvali, M., & Kororos, P. (2009). Physical fitness and anthropometric characteristics in different levels of young team handball players. *The Open Sports Sciences Journal, 2*(1), 22-28.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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