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EVALUATION OF FORCE AND VERTICAL JUMP PERFORMANCE IN YOUNG SWIMMERS WITH DIFFERENT FORCE-TIME CURVE CHARACTERISTICS

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Abstract. The purpose of the present study was to examine the maximum isometric force, force produced in initial 100 ms, and vertical jump performance in swimmers with different force-time curve characteristics, such as the index of rate of force development (IRFD), the index of relative force (IRelF), and the index of reactive force (IReaF). Our results showed that swimmers with high IRFD, IRelF and IReaF values presented higher maximum isometric force, force produced in initial 100 ms, and drop jump height. Thus, the ability to develop high levels of maximum isometric force and vertical jump performance depends on force-time curve characteristics.

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Key words: Isometric force - Drop jump - Squat jump - Swimmers

Introduction

The 50 meters freestyle swim is based on the anaerobic power production system [4]. It is an athletic contest which requires high levels of force and speed [2]. The main aim of the swimming start is to propel the swimmer away from the starting block as quickly as possible and with the greatest momentum that can be developed. Due to this, the swimming block start can be seen as an explosive event with a movement pattern which requires high force production over a short period of time. The time during the start covers almost 25% of the total time needed to swim 25 m and 10% of that needed at the 50 m matches [1].

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The evaluation and design of training programs for the swimming block start and the tumble should be performed according to swimmers' physical condition data [1]. These physical condition data include and the force-time curve characteristics, such as the reactive force index (IReaF), the index of relative force (IRelF), and the index at the rate at which isometric force can be developed (IRFD) [7,11]. These force-time curve characteristics are important capacities of the neuromuscular system to develop maximal force rapidly, and are related to athletic performance [8,10,11,12,15]. The evaluation and design of training programs for the 50-meter freestyle swim do not include the swimmers' force-time curve characteristics. Hence, there are no citations in the literature regarding the vertical jump performance of swimmers.

The purpose of the present study was to examine whether there are differences in maximum isometric force, and vertical jump performance between swimmers with different force-time curve characteristics, such as the index of rate of force development (RFD), the index of relative force (IRelF), and the index of reactive force (IReaF).

Materials and Methods

Table 1
Force-time curve characteristics scale (n=177), [3]

	IRelF	IRFD	IReaF
Excellent	3.3 ►	75% ►	20% ►
Very good	3.0-3.2	68-74 %	15-20%
Good	2.7-3.0	60-68%	10-15%
Satisfactory	2.3-2.7	52-60%	05-10%
Moderate	2.0-2.3	45-52%	00-05%
Low	► 2.0	► 45%	► 0%

Participants: Thirty two (n=32; 14.5±1.3 yrs; 164±4.1 cm; 55.6±4.7 kg) young 50 m freestyle swimmers participated in the present. All participants gave their informed consent, whereas the research design was approved from the review committee of the Aristotle University of Thessaloniki. They were ranked into two groups based on a previous published force-time curve characteristics scale (Table 1) [3]. Especially, the two groups were categorized according to:

a. Their index of reactive force (IReaF = (DJ_{max} – SJ_{max}) / SJ %): the group of those whose index value was above average "$IReaF_{-1}$" with IReaF = -4.28 (±2.10) and the group of those below average "$IReaF_{-2}$" with IReaF = -6.66 (±2.20) [7,11].
b. Their index of rate of force development (IRFD = F_{100}/F_{maxiso} %): the "$IRFD_{-1}$" group with IRFD = 61.65 (±4.88) and the "$IRFD_{-2}$" group with IRFD = 44.06 (±5.36) [7,11].
c. Their relative force index the "$IRelF_{-1}$" group with relative force index = 3.07 (±0.46) (IRelF = F_{maxiso} / body weight) and the "$IRelF_{-2}$" group with IRelF = 2.16 (±0.31) [7,11].

The measurements were conducted in the Sport Biomechanics Laboratory of the Department of Physical Education in Serres (Aristotle University of Thessaloniki).

Measurements: All participants performed the following laboratory test items: a) squat jump from a static semi-squatting position with a knee angle 90^o without using arms, b) drop jump from stands of 10 cm, 20 cm and 30 cm, and c) maximal isometric force of both legs which were measured in a sitting position, so that the knee and hip angles were 90^o. Participants performed three trials for each test and the best trial was recorded. Reliability indexes for the laboratory tests ranged from 0.88 to 0.94 [10]. Before the initiation of the measurements, a 10 min warming up was applied.

Instruments: An AMD - uniaxial load cell with a pliable aluminum plate situated vertically to the ground (accuracy ± 5 Nt and sampling frequency 1000 Hz) was used for the maximal isometric force measurement. A second identical load cell, situated parallel to the ground (with an attached steel plate 0.40x0.40x0.02 m) was used for all vertical jumps. Load cells were connected to an A/D card that transformed the data from analog to digital and to a computer with special designed software for receiving the signal, analysis and further data processing.

Statistical analysis: The statistical package SPSS 11.0 for Windows was used for all statistical analyses. Means ± SD were calculated. Dependent variables in the present study were the maximum isometric force, the force produced the first 100 ms, the squat jump height, and drop jump height. Independent t-tests were applied to examine if there were significant differences between groups with different IRelF, IRFD and IReaF levels in all dependent variables. Statistical significance was accepted at $p \leq 0.05$.

Results

Table 2
Force and vertical jump height in groups with high and low reactive force index

	$IReaF_{-1}$ Group	$IReaF_{-2}$ Group	t-values
Fmaxiso (N)	1198±265*	904±165	-3.67
SJ height (cm)	26.08±3.12	25.61±3.34	0.41
DJ height (cm)	24.45±3.69*	18.26±3.12	-5.12
F_{100} (N)	628±141*	478±137	-3.04

*p≤0.05 significant differences between groups with high and low reactive force index

Significant differences were found in the maximum isometric force (p=0.01), the maximum isometric force at 100 ms (p=0.01), and the maximum DJ height (p=0.001) between the two groups with high and low IReaF values (Table 2).

Table 3
Force and vertical jump height in groups with high and low rate of force development index

	$IRFD_{-1}$ Group	$IRFD_{-2}$ Group	t-values
Fmaxiso (N)	1011±314	1073±314	0.66
SJ height (cm)	25.07±3.68	26.65±2.45	1.41
DJ height (cm)	22.77±9.55*	19.55±4.47	2.07
F_{100} (N)	621±123*	476±156	-2.92

*p≤0.05 significant differences between groups with high and low rate of force development index

The group with high IRFD values presented significantly higher maximum isometric force at 100 ms (p=0.001), and maximum DJ height (p=0.05) in comparison to the group with low IRFD values (Table 3).

Table 4
Force and vertical jump height in groups with high and low rate of the relative force index

	$IRelF_{-1}$ Group	$IRelF_{-2}$ Group	t-values
Fmaxiso (N)	1187±249*	926±218	-3.06
SJ height (cm)	26.2±3.01	25.5±3.35	1.13
DJ height (cm)	23±4.41*	19.7±4.36	-2.08
F_{100} (N)	623±87*	491±176	-2.77

*p≤0.05 significant differences between groups with high and low rate of the relative force index

Significant differences were found in the maximum isometric force ($p<0.01$), the maximum isometric force at 100 ms ($p=0.05$), and the maximum DJ height ($p=0.05$) between the two groups with high and low IRelF values (Table 4).

Additionally, the relative force levels of the swimmers lie at a “satisfactory” level, while those of the index of ReaF were found to be at a “low” level.

Discussion

The findings of the present study showed that swimmers with high IReaF, IRelF, and IRFD values presented higher maximum isometric force, force produced in initial 100 ms, and drop jump height in comparison to swimmers with low IRF, IRelF, and IRFD values.

The relative force levels of the swimmers lie at a “satisfactory” level, while those of the index of ReaF were found to be at a “low” level. This is probably due to the abstention of the swimmers from plyometric training. This could also be attributed to the low levels of coordination in this age group. It is well known that coordination is an important factor which limits performance in jumping exercises [7]. The grouping according to the relative and reactive force indexes and the index of RFD show that even young athletes present statistically significant differences regarding characteristics which concern maximum force, IRFD, and the functioning ability of the muscle system during the fast stretch-shortening cycle (SSC). The results indicate that there seems to be a connection between the maximum force and rate of force development abilities for the achievement of a better performance during a fast SSC in the young biological systems of the swimmers. The ability of performing better vertical jumps by individuals whose relative force indices are higher, is not common in older aged athletes as indicated in similar researches [10,11], but it is common in school-aged children [7].

Moreover, the athletes in the present study that showed higher values of the index of ReaF yielded higher drop jumps as well. Thus, the significance of the role of reflectional contribution and stored elastic energy on the performance of drop jumps becomes evident [5]. Young [15] have reported no relationship between maximal isometric force, rate of force development and vertical jumping performance. Similarly, Viitasalo *et al.* [14] have reported no relationship between maximal isometric force and vertical jumping performance, while Jaric *et al.* [6] reported relatively low relationships between maximal isometric force and vertical jumping height. The results of the present study seem to partially support the findings of these previous studies.

It has been sustained that the start time is almost 25% of the total time needed to swim 25 yards and 10% of the time in 50 m contests [1]. Swimming requires high muscle power in lower limbs in order to achieve a good performance [9]. In an effort to determine the role played by power in adult swimmers, Sharp *et al.* [13] found a close relationship between power output and sprint swimming performance (r=0.90). There are no data concerning the performance of the swimmers in that contest in the present research. It might be truly interesting in some future research to examine whether the athletes in the present research that outclassed in the indices would also excel in the 50-meter freestyle swim contest due to the explosive nature of the swimming block start and the tumble turn time.

Similar researches may also be helpful in the design of a training program so that the individual differences of the athletes could be taken into account and the physical condition characteristics that are here neglected could be incorporated in the training schedule as they might play a significant role in the athlete's performance.

Conclusion

The segregation of output of young swimmers with report in the characteristics of the force-time curve showed us that influences not only the maximal force but also the jumping ability of athletes. This dynamic ability plays an important role in the output of swimmers of small distances so much at the starting phase as also in the short duration of swimming. The evaluation of output of swimmers and the further report in the training programs appears to constitute a basic indicator of output in the young swimmers.

References

1. Adrian M., J.Cooper (1995) Biomechanics of Human Movement. 2nd Ed. Wm. C. Brown Communication Inc., pp. 95-96

2. Hawley J., M.Williams, M.Vickovic, P.Handcock (1992) Muscle power predicts freestyle swimming performance. *Br.J.Sports Med.* 26:151-155

3. Gantiraga E., E.Katartzi, G.Komsis, C.Papadopoulos (2006) Strength and vertical jumping performance characteristics in school-aged boys and girls. *Biol.Sport* 23:367-378

4. Gossor J., B.Blanksby, B.Elliot (1999) The influence of plyometric training on the Freestyle Tumble Turn. *J.Sci.Med.Sport* 2:106-116

5. Horita T., P.Komi, C.Nicol, H.Kyrolainen (1996) Stretch-shortening-cycle mechanical performance in drop jump. *Eur.J.Appl.Physiol.* 73:393-403

6. Jaric S., D.Ristanovic, D.Corcoss (1989) The relationship between muscle kinetic parameters and kinematic variables in complex movement. *Eur.J.Appl.Physiol.* 59:370-376

7. Katartzi E., E.Gantiraga, G.Komsis, C.Papadopoulos (2005) The relationship between specific strength components of lower limps and vertical jumping ability in school-aged children. *J.Hum.Mov.Stud.* 48:227-243

8. Krämer W., R.Newton (1994) Training for improved vertical jump. GSSI, *Sports Sci.Exch.* 7:53

9. Mameletzi D., T.Siatras (2003) Sex differences in isokinetic strength and power of knee muscles in 10–12 year old swimmers. *Isokinet.Exerc.Sci.* 11:231-237

10. Papadopoulos C., K.Salonikidis (2000) Diagnose und Auswertung der motorischen Fahigkeiten Kraft und Schnelligkeit bei jungen Schwimmern. *Leistungssport* 4:14-17

11. Papadopoulos C. (2005) Kinesiology of track and field, Telethrion publishing, Athens, pp. 169-181

12. Schimdtbleicher D. (1984) Entwicklung der Kraft und der Schnelligkeit. In: J.Bauer, K.Bös, R.Singer (Hrsg.) Motorische Entwicklung (Ein Handbuch). Band 106, pp. 129-151

13. Sharp R.L., J.P.Troup, D.L.Costill (1982) Relationship between power and sprint freestyle swimming. *Med.Sci.Sports Exerc.* 14:53-56

14. Viitasalo J., K.Häkkinen, P.Komi (1981) Isometric and dynamic force production and muscle fiber composition in man. *J.Hum.Mov.Stud.* 7:199-209

15. Young W. (1993) Training for speed/strength: Heavy versus light loads. *Natl.Str.Cond.Assoc.J.* 15:4-42

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