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# ENHACEMENT OF SWIMMING KINEMATICS AND PERFORMANCE THROUGH PROPRIOCEPTION

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**ABSTRACT.** Proprioception is closely linked to control of movement, and it has been shown that athletic performance is based on good proprioceptive abilities. The purpose of this study was to examine whether the weighting of the fist joints (in the form of weighted fabric wrist cuffs) has an impact on the swimming technique and thus on performance in freestyle swimming. A number of 16 male subjects with a medium age of 20.74 years took part in our study and were distributed into 2 separate groups: experimental group and control group. Calculations were made using descriptive statistics and the data for the participating subjects proved to be statistically relevant. Using stimulating elements for proprioception can render positive effects on the swimming technique in freestyle swimming and thus on athletes' performance.

***Keywords****: motor control, proprioception, sports performance, training methods*

## Introduction

In the last century, two theories were postulated regarding the command to move: first, it was associated with central signals (Helmholtz, 1867; von Holst, 1954) and second with the peripheral sensory feedback (Sherrington, 1900). However, in the last 50 years, studies have shown that the command to move has a peripheral origin, at least for the perception of limb movement, and the

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focus subsequently shifted to identifying the predominant sensory receptor. Recently, it has been agreed that feedback from muscle spindle receptors is the most important source of proprioceptive information (Gandevia, 1996; Kandel et al., 2000; Smetacek & Mechsner, 2004; Collins et al., 2005), although arguments have also been made over the years for receptors in the joints (Boyd & Roberts, 1953; Ferrell et al., 1987; Gelfan & Carter, 1967) and skin (Edin & Abbs, 1991; Gandevia & McCloskey, 1976; Provins, 1958).

Proprioceptive training is an intervention aimed at improving proprioceptive function. It focuses on the use of somatosensory signals such as proprioceptive or tactile afferents, when there is no information from other modalities such as vision available. (Aman et al., 2014). In this understanding, proprioception can be defined as the ability of an individual to integrate sensory signals from central integrated mechanoreceptors in muscles, tendons, joint capsules, ligaments, and skin (Salles et al., 2015), thereby determining positions and movements of body segments in space (Han et al., 2016, 2013, 2013; Goble, 2010, 2009; Suprak, 2011). Submodalities of proprioception in this relation are: kinestesia, joint position and force sense (Salles et al., 2015).

Later microneurographic studies suggest a possible cutaneous contribution to kinesthesia; cutaneous receptors in the hand (Edin, 1992, 2004; Edin & Abbs, 1991; Grill & Hallet, 1995; Burke et al., 1988; Hulliger et al., 1979) and around the knee (Edin, 2004) may provide information about the position and movement of nearby joints.

A growing number of researchers, particularly in the fields of exercise, sport, and rehabilitation, are recognizing the importance of central processing of proprioception in understanding human movement. For example, there is evidence that central processing of proprioception may play a role in athletic performance (Pop & Ilisei, 2021; Han et al., 2015; Smetacek & Mechsner, 2004).

In competitive sports such as swimming, precise and coordinated body movement is key to success. In recent decades, training methods have changed largely due to the fact that the role played by sensory information in neuroplasticity through use-dependent mechanisms is better understood. Proprioception is considered the most important source for promoting task-specific neural development (Han et al., 2016; Goble, 2010).

As shown in several studies, swimming training programs incorporate elements of resistance training to increase the load on the muscular system. Overloading the muscular system, increases muscle strength and thus the swimming propulsion. This rather direct link between muscle strength and swimming speed has been confirmed in various studies (Gourgoulis et al., 2019, 2006; Barbosa et al., 2008; Cochrane et al., 2015; Dingley et al., 2015; Garrido et al., 2010; 2010; Girold et al., 2012; Morouco et al., 2012; Newton et al., 2002).

Regardless of the apparent training results, it is not certain how strength training affects proprioception, although authors have described the effects of muscle strengthening on proprioception (Salles et al., 2015).

In addition, we did not find studies related to the improvement of coordination and motor control in relation to athletic performance in general and swimming technique in particular. Therefore, the aim of our study was to investigate the effect of loading the distal upper extremity with weighted fabric wrist cuffs on swimming technique during front crawl stroke (FCS).

## Methods

### *Sample*

16 male undergraduates (average age 20.74 years, mean height 176.3 cm, mean weight 73.8 kg) were part of this study. The subjects have been swimming for 3 ±0.2 years on average and on a regular basis, taking part in 3 training sessions/week. All subjects were in good health condition, without any history of upper limb injuries. They were divided equally and randomly distributed in 2 groups: control group and experimental group. All participants were asked to sign an informed consent document before entering the study.

### *Experimental Procedure*

Participants were briefed not to perform any other swimming activities during the 8 weeks of the experiment, to reduce any potential influence on the study results. For 8 weeks, both the control and the experimental group attended the swimming program consisting of 3 sessions per week (Monday, Wednesday, and Friday) at the same time and place. After an 800 m warmup by choice at moderate speed, each swimming session consisted of drills meant to improve the FCS technique. Emphasis was laid on one-arm drills, followed by combined exercises closer to the full stroke on 50 m. The experiment group put on the weighted fabric wrist cuffs (WFWC) after completing the warmup and removed them after finalizing the FCS technique drills. WFWC weighed 150 grams.

### *Measurements*

We measured the time necessary to complete 50 m FCS, starting from the water using a FINIS 3x300M stopwatch. We decided upon this approach, in order to rule out potential differences based on poor/good start from the block. Each subject had 2 attempts with 3 minutes in between. The best attempt was recorded as the initial time. The same procedure was repeated after the experimental period of 8 weeks.

### *Statistical Analysis*

We computed average values for each measurement, both for the initial and the final ones using SPSS, IBM Corporation Armonk, NY.

The distribution of the measured parameters was determined using the Shapiro - Wilk Distribution Test prior to statistical testing. Based on the results of the test (value of the distribution coefficient, p), a normal distribution was found for the parameters measured in the initial measurements and in the final measurements; a normal distribution was also found for the experimental group ($p > 0.05$ in each of the mentioned measurements). The normal distribution determined in both measurements denotes a linear evolution/involution of the subjects (all subjects responded similarly after training).

**Table 1.** Descriptive analysis – time parameter

| Group | Mean value | Standard deviation | Median | Shapiro – Wilk |
|---|---|---|---|---|
| Initial measurement | | | | |
| Time 1 – control group | 51.84 | ± 6.239 | 50.84 | 0.901 |
| Time 1 – experiment group | 39.85 | ± 5.98 | 39.24 | 0.08 |
| Final measurement | | | | |
| Time 2 – control group | 48.65 | ± 5.32 | 47.51 | 0.554 |
| Time 2 – experiment group | 37.5 | ± 6.21 | 35.99 | 0.057 |

**Table 2.** Descriptive analysis – speed parameter

| Group | Mean value | Standard deviation | Median | Shapiro – Wilk |
|---|---|---|---|---|
| Initial measurement | | | | |
| Speed 1 – control group | 0.975 | ± 0.118 | 0.98 | 0.961 |
| Speed 1 – experiment group | 1.27 | ± 0.167 | 1.27 | 0.490 |
| Final measurement | | | | |
| Speed 1 – control group | 1.03 | ± 0.106 | 1.05 | 0.728 |
| Speed 1 – experiment group | 1.36 | ± 0.186 | 1.34 | 0.239 |

The t-test for paired samples and the t-test for independence were used to determine statistically significant differences and to validate the results obtained in both groups.

The paired samples t-test was used to check whether there were significant differences within the groups between the initial and final tests. In the control group, the results obtained led to the conclusion that the statistical analysis performed made it possible to detect non-significant differences between the initial and final test for both the time and speed parameters. The value of the statistical coefficient p in both cases was $p = 0.072$ and $p = 0.054$, respectively, values that are above the threshold of 0.05, confirming the null hypothesis and refuting the initial hypothesis. In other words, no increase in performance can be detected between the two tests. It must be stated that differences in performance were there from the beginning between the two groups. The mean of the control group determined based of the initial test is 51.84 sec, while the same mean determined for the experimental group is 39.85 sec. This difference was also statistically proven following the Independence t-Test.

After both the first and the last test, the statistical coefficient p was calculated. Based on this coefficient, it was found that there were statistically significant differences after both the first and the last test (p = 0.001 and p = 0.002, respectively).

However, within the experimental group, the obtained results led to the conclusion that the performed statistical analysis allowed the identification of significant differences between the initial and the final test, both in terms of the parameter of time and the parameter of speed. The value of the statistical coefficient p in both cases was p = 0.015 and p = 0.012, respectively. It can be noted that both values are below the threshold of 0.05, which leads to rejecting the null hypothesis and confirming the hypothesis we proposed.

## Discussion

This study primarily aimed at providing a training method for increasing FCS performance through improved technique. We investigated whether applying WFWCs has an influence on a better understanding of the FCS swimming technique on 50 m events.

We wanted to analyze if there is a causal relation between the stimulation of proprioception and the development of swimming performance through improvement of motor control. Starting from previous studies which revealed that visualising the execution of certain movements in a mirror improves the quality of execution (Pop et al., 2016), we assumed that using WFWCs will stimulate motor control through activating proprioception.

The buoyancy phenomenon diminishes kinesthesia (sense of motion and position of limb segments). If some authors claim that afferents transmitted through proprioceptive mechanisms are ambiguous in a full gravity environment (Feldman, 2009), then this mechanism is even less reliable in the water. Nonetheless, a correct perception of the body and thus absolute motor control is necessary to achieve swimming performance.

The approach we started from is used as a treatment method in adults with static brain lesions, where studies prove that weighted distal upper extremity using WFWCs increases the input of proprioception and has a positive influence on biomechanical parameters (McGrunder et al., 2020). Although weighting in our study meant using the same load – according to some studies this set-up leads to the proprioceptive muscle spindles becoming more sensitive (Salles et al., 2015) – our results show an improvement in performance: statistically significant (p = 0,072) enhancement in time, final measurements as compared to initial measurements, as well as in speed (p = 0,054).

The obvious limitation of the study is represented by the suggested approach to compare the experimental group to the control group. As anticipated and discussed above, the results of the control group showed not statistical relevance. At the end of the study, it became clear that the relevant statistical differences are within the experimental group: initial as compared to final time and speed. Nonetheless, the control group functioned as an additional verification factor.

## Conclusions

To our knowledge, we are the first to investigate the effects of distal upper extremity loading on improving technique and performance in swimming. Training with WFWC led to performance improvement of the FCS technique on 50 m, an improvement proven by the tests. A simple comparison can lead to the observation that the control group, which did not train using WFWC, did not experience significant evolution in performance, while the experiment group, which trained using WFWC, experienced a significant improvement in performance.

The results indicate that training with WFWC is related to improvements in motor control and coordination of the upper limbs during 50 m FCS events. It has been confirmed that stimulation of muscle spindle receptors, which are the main source of proprioceptive information, can have a positive effect on athletic performance, even in a less stable environment such as water. However, more research on this topic is needed to establish its evidence.

The next step in our research will be investigating the kinematic and kinetic effects of using this type of proprioceptive training since this study focused more on analysing the swimmer’s performance.

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