ORIGINAL RESEARCH

EFFECT OF PLYOMETRIC TRAINING ON SWIMMING BLOCK START PERFORMANCE IN ADOLESCENTS

Running Head: *Plyometrics and Swim Start Performance*

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ABSTRACT

The study aimed to identify the effect of plyometric training, when added to habitual training regimes, on swim start performance. Following the completion of a baseline competitive swim start, 22 adolescent swimmers were randomised assigned to either a plyometric training (PT; n =11, age: 13.1 ± 1.4 yrs, mass: 50.6 ± 12.3 kg, stature: 162.9 ± 11.9 cm) or habitual training group (HT: n =11, age: 12.6 ± 1.9 yrs, mass: 43.3 ± 11.6 kg, stature: 157.6 ± 11.9 cm). Over an 8-week pre-season period, HT group continued with their normal training programme, whilst the PT group added two additional 1-hr plyometric-specific sessions, incorporating prescribed exercises relating to the swimming block start (SBS). Following completion of the training intervention, post-training swim start performance was re-assessed. For both baseline and post-trials, swim performance was recorded using videography (50Hz Canon MVX460) in the sagital plane of motion. Through the use of Silicon Coach Pro analysis package findings revealed significantly greater change between baseline and post-trials for PT when compared to HT group for swim performance time to 5.5 m (-0.59s vs. -0.21s; P <0.01) and velocity of take-off to contact (0.19 ms^{-1} vs. -0.07 ms^{-1}; P <0.01). Considering the practical importance of a successful swim start to overall performance outcome, the current study has found that inclusion of suitable and safely implemented plyometric training to adolescent performers, in addition to habitual training routines, can have a positive impact on swim start performance.

Key Words: power production, overload, swim time

INTRODUCTION

Referring to physical movements characterised by forceful contractions in response to myostatic-stretching of active muscles (8), the use of plyometrics as a means of encouraging the muscle to achieve maximal force rapidly and therefore serving to increase explosive-reactive power through a range of motion is a popular training approach (8). By developing the efficiency of the neuromuscular system in achieving maximum explosive-reactive power, the application of plyometric training (PT) as a means to developing the performer has lead to wide use within sports that require fast explosive movements (2).

Established as a valuable strategy for enhancing force generating potential of explosive-reactive movements, the effectiveness of such training approach depends on the incorporation of sport-specific movements, applied through appropriate frequency and intensity over extended periods. With explosive sports requiring rapid maximal muscular force production, such appropriate manipulation of the stretch-shortening cycle to increase efficiency has had a consequential positive effect on sports performance (3). By developing the muscular-reflex to withstand high-stretch loads, combined with the decreased neural disinhibition of muscle proprioceptors, PT produces neuromuscular adaptation and specific muscular activation for coordinated movement patterns, thereby enhancing contraction force (12).

Investigating the impact of PT on dynamic movement activity, Lathrop *et al*. (7) have reported substantial improvements in running economy (4.7%) and 3200m cross-country running times (3.9%) in adolescent performers, whilst Matavulj *et al*. (10) recorded enhancements in vertical jump economy and height of junior basketball players. With significant improvements also being found following PT in 40m skating speed in junior ice hockey players (8), the appliance of sport-specific plyometric training as a means of improving muscular functioning has a practical importance to sports performance. Despite however the growing body of evidence elucidating to the value of PT in a range of sporting activities, the value to such approach to swimming has had little investigation. Although once in the water, performance benefits of PT may be negligible, when considered that the swimming block start (SBS), which requires explosive-reactive muscular response, accounts for up to 30 percent of total 50m race time (9), any improvements within this aspect of swim performance could have a significant impact on overall race success. Furthermore, with winning margins being as small as 0.01 of a second in sprint swimming events (11), an appropriate intervention strategy to enhance explosive power output and increase performance efficiency during the SBS may have a meaningful impact on overall swim time.

The age at which one is physically able to participate in a plyometric training programme has not been determined, however guidelines have been prescribed to assist in developing appropriate programmes for adolescents. To reduce the risk of injury and facilitate the performance of plyometric exercises, programmes must initially focus upon technique using low impact exercises before progressing onto higher impact activities. It is recommended that athletes must have a sound understanding of plyometric and landing techniques and possess a sufficient base of strength, speed and balance. Other factors such as landing surface, training area, equipment, proper footwear and supervision must also be assessed, as with any plyometric training programmes (1). Such ramifications to the implementation of plyometric training within developing performers must be paramount to those wishing to promote the effectiveness of such training approach.

Considering therefore the important contribution swim block start plays to overall swim performance and appreciating the explosive-reactive nature of such movement, the aim of the study was to evaluate the effectiveness of a swimming-specific PT programme on start performance. By selecting adolescent competitive swimmers, the study hopes to provide the practitioner with appropriate guidelines when implementing plyometric drills to develop adolescent swimmers performance capabilities.

METHODS

Approach to the Problem

The research hypotheses were examined by way of an experimental design comprising of two independent groups (IV). Following the completion of a baseline trial, which measured a range of SBS performance dependent variables, subjects were assigned through random selection, to one of the groups. After which the groups followed either their normal habitual training programme or a plyometric programme for an eight-week period. Following the intervention period, both groups were re-assessed by completing the SBS performance trial.

Subjects

Recruiting subjects from local swimming clubs, criteria for inclusion was applied to ensure all swimmers were aged 10 to 16 years and engaged in a minimum 8 hours aquatic training per week. All were considered highly competent in executing the SBS by the lead investigator and coach and all had achieved a minimum of regional standard within the past 18 months. Prior to the commencement of any engagement with the subjects, ethics consent was granted through the University ethics committee and adhered to throughout the investigation. Subjects were informed of any potential risks to participation and all provided written informed consent, including consent from a parent/guardian, in accordance with institutional regulations. The investigation experienced no withdrawals and subject baseline measures and characteristics are displayed in Table 1.

[Insert Table 1 here]

Procedures

Prior to initiating the baseline swimming block start (SBS) trial, subjects were required to conduct a standardised fifteen-minute aquatic warm-up prescribed by club coaches, representing time allocated to swimmers prior to competition. Making a recorded note of performed practices, subjects were then asked to get themselves ready to perform under race conditions. In accordance with Amateur Swimming Association competitive start procedures, subjects mounted the blocks, adopted their preferred starting position and were counted down. Throughout each SBS trial, subject's performance was filmed using a Canon MVX460 camcorder at 50Hz in the sagital plane of motion. The camera was positioned parallel to the motion 10-metres from the subject along the poolside and 2 metres from the starting blocks.

Following completion of the baseline SBS trial, subjects were randomly assigned to either the plyometric training (PT) group or habitual training (HT) group. Over a period of eight weeks, all subjects followed the same normal habitual aquatic training patterns, however the PT group were provided with an additional 2 hours per week of specific plyometric exercises. Exercises implemented into PT programme are displayed in Table 2. Included within are the details pertaining to the number of sets, reps, recovery periods and box/hurdle heights. Subjects were required to conduct a 10 minute standardised dynamic warm-up prior to each PT session to increase the subject's mobility and ensure exercises could be performed safely in accordance with Radcliffe and Farentinos (14) who advocate that dynamic preparatory activities 'excite the neuromuscular system without undue fatigue'. The exercises implemented within the PT programme were selected based upon their specificity to the SBS. Particular consideration was placed on ensuring boxes and hurdles were consistent with recommended heights for adolescents to ensure sufficient muscular overload could be achieved safely. (See Table 2 for details of the training programme). Normative values with reference to box and barrier heights ensured that training adhered to the requirements of safety and welfare of the subjects while ensuring that sufficient overload was achieved (refer to Table 3 for details).

[Insert Table 2 here]

Beachle and Earle (1) have reported that overload can be established with appropriate levels of training frequency, intensity, volume and recovery in a 6 to 8 week period. Furthermore, considering the subject group used in this study, the PT programme was developed over an 8 week period to ensure gradual and safe progression within the adolescent performers. Chu (4) further noted that explosive-reactive power is established by implementing numerous sets of less than 6 repetitions at more than 90 percent of one repetition maximum with reference to the adult population. With Radcliffe and Farentinos (14) commenting that the intensity of PT programme should reflect that of competitive performance, but in considering the population-specific group in this study, variables affecting the intensity such as box heights and repetitions were adjusted to ensure they were appropriate to the group.

From the PT group, subjects were subjectively assessed by a qualified strength and conditioning specialist to determine the subject's levels of competency and adaptability to the PT programme. If deemed necessary, intensity and volume were subsequently increased to ensure appropriate muscular overload. Intensity was increased by altering exercise variables including: numbers of repetitions and sets and/or elevated heights of boxes and hurdles. Table 3 provides a guide to the pre-determined training programme with any increases in overload remaining appropriate to subject's requirements and training recommendations as set by Baechle and Earle (1), Chu (4) and Radcliffe and Farentinos (14) to ensure safety.

[Insert Table 3 here]

For the habitual training group, monitoring occurred throughout the eight week period, however, no manipulation of training intensity and/or volume was made. Following the completion of the eight week training programme, all subjects returned to the pool to undertake a second SBS trial. Adhering to their baseline trial strategy, each subject undertook their 15 minute aquatic warm-up after which completed the trial under race conditions. Matching the camera position with the baseline trial, performance was once again videoed, allowing for comparitive analysis.

Through the use of Silicon Coach Pro (siliconCOACH Ltd, New Zealand) each subject’s footage was uploaded and subsequently analysed to determine the time from the starting stimulus to contact of the head with the water surface, the distance from the starting stimulus to contact of the head with the water surface, the velocity of take-off to contact of the water surface, that angles relating to release off the blocks and angle entering the water. The dependant variables of time, distance, velocity and angles were identified as the key determinants of the SBS technique (11). The time to complete a distance of 5.5 metres from the starting stimulus, defined with visual reference points on the lane markers and poolside. The rationale behind inclusion of performance time to 5.5 metres was that with the PT measuring the development of explosive-reactive power, any increase in distance would be reliant upon variables such as kick strength rather than assessing SBS force production (5).

Statistical Analyses

To determine whether the PT programme had a significant impact on measures monitored during the SBS trial when compared to habitual training, data was subjected to a two-tailed independent T-test on the change between baseline-post implementation of the training intervention. To evaluate within group differences for performance measures, a two-tailed dependent T-test was administered. Prior to the completion of the inferential analysis, a Kolmogorov-smirnov test for normality and Mauchley test for homogeneity of variance were conducted. Further correlational analysis in the form of Pearson product moment coefficients, were performed to establish relationships between SBS parameters and 5.5 metre performance time. For all statistical analyses alpha was set at the 95% probability level (P <0.05). Standard error of the estimates (SE_E) were calculated from linear regression analyses to express the precision of estimate in absolute terms.

RESULTS

Comparison of swim block start (SBS) performance measures revealed significant differences between the plyometric (PT) and habitual (HT) training groups (Table 4). Between group baseline-post trial scores for swim performance time to 5.5 m, findings revealed a significantly greater change for the PT group when compared to the HT group (P < 0.01). Similarly, significantly greater change occurred across baseline-post trials for the PT group was compared with the HT group for velocity of the take-off to contact (P <0.01), distance to head contact (P <0.01) and time to head contact (P = 0.023). Interestingly, no significance was found for the angle out of blocks (P = 0.12) and angle of entry into water (P = 0.27) between the PT and HT training groups.

[Insert Table 4 Here]

Analysis of the within group differences between baseline-post trial measures revealed (Table 4) that swim time of 5.5 m was statistically lower (P <0.001) for the PT group, however no significance was found for the HT group (P = 0.11). Further examination also identified time to head contact from the PT group to be significantly lower following plyometric training intervention (P <0.01) whilst no statistical difference was found for the HT group (P = 0.42). Within training groups, significant differences for angle out of blocks, distance to head contact and SBS velocity were also found following their respective 8-week training programme (Table 4).

The association between SBS velocity and swim performance time to 5.5 m for both groups across baseline and post trials was determined to identify the extent of correlational change following 8-weeks of specified training (Figure 1 & 2). For the PT baseline trial, analysis revealed a significant relationship between the measures ($r = -0.66$, $P < 0.05$), which was strengthened following the intervention period ($r = -0.91$, $P < 0.01$) detailed in figure 1. Accounting for 83% of the total variance explained, standard errors of estimates (SEE) for the two associations reduced by 50%, from 0.14s to 0.07s. For the HT group, a significant association was found between SBS velocity and performance time to 5.5 m for the baseline measures ($r = -0.69$, $P < 0.05$) however remained relatively unchanged for the post trial ($r = -0.58$, $P < 0.05$) detailed in figure 2. Examining the SEE for both associations revealed a marginal increase in error for the post (0.32s) when compared to the baseline assessment (0.35s).

[Insert Figure 1 & 2 Here]

Distance to head contact and swim time to 5.5 m was also significantly correlated for the baseline assessment for both the PT ($r = 0.82$, $P < 0.01$) and HT group ($r = 0.66$, $P < 0.05$). The post-trial association between distance to head contact and time to 5.5m in the PT group was strengthened slightly ($r = 0.88$, $P < 0.01$) following training, however for the HT group, reduction in the degree of association found ($r = 0.31$, $P > 0.05$). Interestingly, an insignificant association was revealed for time to head contact and time to 5.5 m for the baseline assessment in the PT group ($r = 0.019$, $P > 0.05$) and the HT group ($r = 0.10$, $p > 0.05$). Evaluating the post-trial associations however revealed a marginal change for PT group ($r = 0.13$, $P > 0.05$) and HT group ($r = 0.40$, $P > 0.05$), respectively.

DISCUSSION

The purpose of this study was to evaluate the effectiveness of a swimming-specific PT programme on SBS performance in adolescent competitors. The major finding identified that by engaging in explosive-power training sessions, additional to habitual aquatic regimes, swim time to 5.5 metres significantly improved on average by 0.59 seconds, equating to a 15% improvement in performance time. With the habitual training group not exhibiting any significant change in time to 5.5 metres, it can be assumed that exposure to 2 hours supplementary training per week had a meaningful impact on the swimmers ability to cover the distance quicker.

With enhancements of flight dynamics following swim block release thought to significantly impact on the quality of SBS performance (16), the present study confirms that as a consequence of plyometric training, significant reductions in time to head contact and greater distance to head contact more than likely contributed to the improvements in performance time. Indicating that performers were able to generate greater release speed and power off the block, translating into faster times to 5.5 metres, signifies to the practitioner that supplementary plyometric training offers a valuable means of developing this important aspect of overall swim performance success (9).

By investigating the association between SBS velocity and performance time to 5.5 metres before and after the intervention in both training groups revealed further important practical implications to the coach. Examination of the findings indicated that as a consequence of plyometric training, the velocity from release to water contact resulted in a stronger relationship (r = -0.91) with performance time than prior to the intervention (r = -0.66). Such improvement in the association between an important SBS variable and the key performance indicator, coupled with a meaningful reduction in the standard error of the estimate, signifies the important contribution SBS velocity must play in the achievement of reducing swim time over the first 5.5 metres. For the coach working with the swimmer, exercises that focus on developing the velocity of release will have a significant impact on overall swim start performance. Ensuring the performer is able to maximise the power off the block by accelerating quickly, increases in distance and time to head contact will allow for faster transit through the water once entered. Establishing whether significant improvements in SBS exist following intervention requires practitioners to provide quantitative interpretations into the ‘flight phase’ prior to contact with the water (15). Considering the complexity of such approach, research studies investigating SBS variables and their impact on key performance indicators are needed. This being the case the present study is the first to provide conclusive evidence that swim performance time enhancement is attributable to both increased flight distance and time.

With significant changes reported for angle out of the block, distance to head contact, time to head contact and consequently SBS velocity, it would appear that the implementation of the plyometric training intervention provided an adaptive response that allowed for greater power production off the blocks. Although documented evidence does highlight the importance of sport-specific plyometric training to the enhancement of muscular force-generating capacity and neuromuscular development (3, 7, 8, 10, 12), limited evidence, linking plyometric training and swimming-specific block starts has been reported. One such study to do so however, did conclude that following a training intervention programme, no significant improvements in SBS were found (6). Examination of approach does reveal however that implementation of the plyometric training intervention did not take into consideration adaptation and progression through the 6-week schedule. For the current study, increases in intensity and volume reflected levels of competency and adaptability to the PT programme over the 8 week period. Continually assessing the swimmer and adjusting their training stimulus accordingly ensured that all swimmers engaged in activities suited to the adaptive responsiveness to the programme and provided a more realistic approach to the management and implementation of tailored training regimes.

With swimmers continuing to engage in their normal habitual training patterns, the study provided further insight into SBS performance from non-plyometric specific training. Findings indicated that despite the habitual group significantly increasing their take-off angle out of the blocks across trials, swimmers showed a decrease in both distance to head contact and SBS velocity, with a concomitant increase in time to head contact. With the habitual training group not performing any land-based plyometric training exercises it can be concluded that although aspects of SBS performance altered, an inability to produce sufficient power to transfer the increased take-off angle into meaningful improvements resulted in insignificant changes in swim performance time.

Sport-specific PT effectively stimulates muscle spindles, involving agonist muscle preloading and elastic energy storage. Through the manipulation of intensity and volume, the force-generating capacity of the stretch-shortening cycle to initiate forceful muscular contractions can be altered (1). Allowing for more purposeful and deliberate exercise tasks, Brandon (2) highlights therefore the important responsibility practitioners and coaches have in implementing appropriate training frequency and intensity to enhance such force-velocity relationship of skeletal muscle. The optimisation of eccentric force production significantly develops elastic muscular components and explosive power production through enhanced motor unit firing rates and development of contraction intensity involved in neurophysical potentiation (13). Influencing muscular power output and force production, the safe implementation of plyometric training in addition to habitual aquatic-based drills in the current study successfully demonstrates the ability to explosively manoeuvre from the block start position to cover greater distances in significantly faster times.

PRACTICAL APPLICATIONS

Considering the importance of the SBS to overall race performance, the development of effectively managed plyometric training programmes for adolescent swimmers can have a meaningful impact on overall race success. When devising such PT programmes, it is imperative that the athletes are provided with adequate supervision and assessment to avoid injury due to poor technique and excessive overload to the muscles. The initial development of the programme should therefore be low to moderate in intensity and focus upon the technical proficiency of the exercises utilised to avoid injury. The exercises should be specific to the movements in which increased power production is sought and should provide a progressive overload through increases in both intensity and volume. Progression to higher overload intensities can be manipulated through altering exercises and increasing the number of repetitions and sets and/or elevated heights of boxes and hurdles.

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