Effectiveness of a dry-land resistance training program on strength, power and swimming performance in Paralympic swimmers

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Title: Effectiveness of a dry-land resistance training program on strength, power and swimming performance in Paralympic swimmers

Laboratory:
All research was carried out at the Australian Institute of Sport, Canberra, Australia.

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ABSTRACT

This study evaluated the effectiveness of a dry-land resistance training program in Paralympic swimmers to increase swimming power and strength measures, and how these changes affect swimming performance. Seven elite-level Paralympic swimmers (1 male and 6 female; age 19.4 ± 6.5 y; body mass 57 ± 12 kg; height: 1.66 ± 0.21 m) performed a 6-week coach-prescribed strength training intervention program designed to improve power, flexibility and postural control. Exercises targeted the main swimming movements: the start and turn, postural control in the water, and the pull and kick focusing on the gluteals, upper body and trunk. Swimming-specific tests, involving a 50-m time trial, and timed dive starts were conducted at baseline and after the 6-week program. A bilateral swim-bench ergometer and jump tests were conducted to quantify arm and leg strength and power. Following the 6-week intervention, 50-m time trials improved by 1.2%, ±1.5% (mean, ±90% confidence limits). Increases in both mean power (6.1%, ±5.9%) and acceleration (3.7%, ±3.7%) generated during the dive start enabled swimmers to substantially improve start times to the 5-m (5.5%, ±3.2) and 15-m (1.8%, ±1.1%) marks. The resistance training intervention resulted in a very large (r=0.78, ±0.37) correlation between dive start velocity and the counter movement jump mean velocity. The 6-week resistance training program for Paralympic swimmers yielded substantial improvements in dry-land measures that corresponded with improvements in both timed dive starts and 50-m time trial performance, thus highlighting the usefulness of dry-land training for enhancing swimming performance in Paralympic swimming.

Key Words: resistance program, intervention, Paralympic swimming
INTRODUCTION

Competitive swimming is about covering a given distance in the shortest period of time—and is determined by the swimmer who is able to maintain the greatest power output for a given distance in an efficient and skillful manner to overcome the resistance of the water (18, 19). Two primary factors in determining swimming performance (15, 19, 34), particularly over sprint distances (35) are muscular strength and power. Substantial correlations between upper-body muscular strength and power output and velocity of swimmers have been shown over sprint distances (3, 37), with improvements in swimming performance associated with increases in power output (29, 37).

Fitness training for swimming has two main approaches: using traditional pool-based training in water (endurance training) and dry-land methods on the pool deck or in the gym (strength training) (15). By overloading the muscles required for swimming, a dry-land program aims at increasing the swimmer’s maximal power output (34) and thus velocity. An important consideration in the design of a dry-land program is specificity of the training methods, since swimming performance improvements depend on this principle (9, 20, 31) therefore the selected exercises should be consistent with the types of movement that are involved in swimming (18). The main movements in swimming are arm rotation, kicking, jumping and body rotation.

A loss of strength, co-ordination or range of motion within the kinetic chain can cause a swimmer to fall short of their potential performance (24, 27, 28) and the deficits in muscle or joint flexibility, muscular stability and muscular control that occur can lead to decreased efficiency and an increased chance of injury (5, 26). The most common anatomical regions
with musculoskeletal issues in swimming are: (i) hip flexors and gluteals, which have implications for starts and turns, as well as kicking; (ii) shoulder girdle, with stronger internal rather than external rotators (27) often leading to shoulder injuries (38); and (iii) overactive upper abdominal muscles compared with weaker lower abdominal muscles, leading to a lack of control of the pelvic position influencing poor body position in the water. In Paralympic swimming, swimmers have physical or non-physical disabilities (blind or intellectual). By the nature of their physical impairment many Paralympic swimmers exhibit larger muscular imbalances, limitations in muscle and joint flexibility, and less stability and control of the muscles (27). Therefore a coach-prescribed strength training program would be beneficial to improve strength, flexibility and control of the muscles required for specific swimming movements.

In competitive swimming, an effective start off the blocks is an important component (6, 7) contributing up to 26% (8, 30) of total race time in sprint distances and is the stage where velocity is greatest (2, 7). To produce a fast entry, the important requirements are a high take-off velocity and a streamlined position underwater to maximize and maintain velocity for as long as possible (7, 11). In Paralympic swimmers it appears the underwater phase is a critical phase with those swimmers with a greater severity of physical disability or having a disability that affects their lower body (e.g. cerebral palsy or leg amputees) disadvantaged in this kick dominant phase and spending a greater proportion of time in the free swim phase (11). The dive start is the stage of a swim where the highest velocities throughout the entire race are recorded (2, 7, 39), therefore fast starts are reliant on explosiveness with a powerful leg drive an important component (18). Previous studies have found significant correlations between starting performance in swimmers and measures of lower body power in able-bodied swimmers (6, 22). Therefore improvements in jumping ability and muscular leg power, may
improve a swimmer’s start time (17). Clearly the focus is to develop sports-specific strength and power to enhance dive starts and free swimming velocity.

Paralympic swimmers compete in 14 classes: locomotor impairments are grouped for classes 1 (most severe disabilities) to class 10 (least severe disabilities). Swimmers with a visual impairment are in classes 11-13, and those with an intellectual impairment form class 14. In the locomotor impairment classes there are a large range of physical disabilities that variously affect the whole body (e.g. cerebral palsy and small statured), lower limb (e.g. leg amputee or spinal-cord injury) or upper-limb (e.g. arm amputee) (13). Therefore the challenge for prescription of dry-land programs is even greater in Paralympic swimming given the diverse nature of the disabilities. Inclusion of speed training and drills, as well as a strength element in the program, should also be effective in improving a swimmer’s sprint performance (14, 15). To the authors knowledge there is no published research on dry-land programs for Paralympic swimmers which is surprising given the rising interest and investment in Paralympic sports by many leading sporting nations.

Therefore, the primary aim of this study was to evaluate the effectiveness of a dry-land program that focuses on improving measures of power and strength in Paralympic swimmers. A secondary aim was to determine whether these improvements transfer to swimming performance in Paralympic swimmers. This study tested the hypothesis that a dry-land strength training program would led to improvements in swim-starts and faster sprint performance, greater than the typical yearly improvements reported in Paralympic swimming of ~0.5% (12), and within the improvement range of 1.3% and 4.4% of existing studies of the effect of dry-land strength programs on sprint performances in able-bodied swimmers (9, 32).
METHODS

Experimental Approach to the Problem

During preparations for the Paralympic selection trials (March), a 6-week pre-post experimental trial examined the effect of a dry-land program on strength and power measures and swimming-specific movement patterns. The intervention was completed 4 weeks prior to competition. Given the unique physical characteristics and limited numbers of these international level athletes we employed a single experimental group design of high ecological validity albeit with some limitations in experimental control.

Over a period of 72 hours, each swimmer undertook five different testing sessions in clinical (anthropometry), laboratory (jump testing and swim-bench ergometry) and pool (time trial and timed dive starts) settings. To minimize the effects of residual or cumulative fatigue from daily training on test performance, swimmers and coaches were asked to avoid any stressful training on the days prior to and during the testing period. No changes in the diet were requested.

Subjects

In this study, seven (1 male and 6 females) elite Paralympic swimmers (age 19.4 ± 6.5 y; body mass 57 ± 12 kg; height 1.66 ± 0.21 m; mean ± SD) participated in this study. All subjects competed at the 2012 Paralympic Games in the following classes S14 (intellectual 17 y), S13 (visually impaired, 20 y), S10 (cerebral palsy, 16 y), S9 (leg amputee, 20 y), S8 (cerebral palsy, 13 y), and S6 (cerebral palsy, 17 y and small statured, 33 y). Written informed consent was obtained from the subjects, prior to voluntarily participation in the
study for participants over 18 years of age, while for minors and the intellectually disabled subject a guardian and the subject provided written informed consent. The study was approved by the Ethics Committee of the Australian Institute of Sport (approval number 20110809), and the University of Sunshine Coast, Queensland, Australia.

Dry land Training Program

A 6-week strength program was designed to improve strength, flexibility and control of three main functional qualities while also developing power. The program incorporated exercises specifically targeting the main movements in swimming: the start and turn, postural control in the water, and the pull and kick. Three times per week (Monday, Wednesday, Friday), swimmers performed exercises that focused on the (i) lower body for development of control and power through the gluteals (e.g. medicine ball prone chest throw on a glute-ham raise bench and 2x2-m grid monster walk in each direction), (ii) upper body for strengthening of the stability of the shoulder girdle (e.g. push press and weighted narrow grip chins), (iii) trunk for activation and control of the core (e.g. prone bridge and swimmer's roll). Strength training sessions were 60 min long with a 5 min warm-up on a cycle ergometer, followed by five warm-up/injury prevention exercises (e.g. swissball freestyle kick and TRX stop signs). The same format was followed in session with three exercises focusing on each area with a 2 min rest between each set. A maximum of 8 repetitions, with an average of 6 repetitions per set was met, with 3 sets per exercise. Intensity of the training varied from 90% (weeks 1 & 4), 95% (week 2), 102% (weeks 3 & 5) and 85% (week 6). The session ended with two abdominal exercises (e.g. weighted seated Russian twist and bench oblique crunches) for which 20 repetitions or 55 secs. The aim was to develop movement by binding all of these structural and functional components in order for the kinetic chain to deliver forces in a coordinated fashion.
**Body Composition** (Day 1, 6 - 8AM)

Swimmers presented between 6 am and 8 am in a fasted state, and an anthropometric profile was conducted by a Level 3 accredited anthropometrist, in accordance with the recommended methods of the International Society for the Advancement of Kinanthropometry (21). Body mass, stretch stature, skinfold thickness at seven sites and chest circumference were recorded. Changes in lean mass were quantified using the LMI index previous validated for swimmers (23).

**Strength and Power Assessment**

**Swim Bench (Day 1, 2 - 4PM)**

A calibrated bilateral swim-bench ergometer (Weba Sport, Wien, Austria) was used to measure the force produced in left and right arms respectively during simulated freestyle. After a standardized 10 min warm up, swimmers performed two x 60 sec maximal freestyle efforts with a 5 min rest period between trials. During efforts, encouragement was limited to the 15, 30 and 45 sec periods to coincide with informing the swimmer of time progression of trial. The swimmer was lying in a prone position on the bench with their hips attached to the bench using a strap (33). Each arm stroke was measured independently and the mean power and peak force recorded. The standard error of measurement in our laboratory is 2 N and 2 N respectively.

**Jump Testing (Day 2, 10 - 12AM)**

Subjects undertook a 10 min standardized warm-up that consisted of 5 min cycling on a cycle ergometer and 5 min dynamic stretches, followed by a jump testing protocol to estimate lower body power and velocity. The jump test protocol, involved five countermovement
jumps and five squat jumps at body mass, separated by a 2 min rest period. All jump
movements were video-recorded with the use of a 50 Hz Sony digital camera (TRV950 –
Sony Corporation, Tokyo Japan) to allow for the confirmation of correct technique. Any
jump that was not deemed to be performed correctly was repeated. To maintain correct
execution of the squat jump subjects would hold a stable position at the bottom of the squat
for 1-2 secs, and from there move upwards, rapidly extending the legs and the hips (avoiding
any counter movement (pre-stretch) around the knee and hip joints). The Gymaware system
(Kinetic Performance, Mitchell, ACT, Australia) was used to collect data on power and
velocity for both tests, with the standard error of measurement 0.05 m/sec.

Swimming Specific Assessment

50-m Time Trial (Day 3, 6 - 8AM)
In a 50-m pool after a 1000 m individualized pre-race up, each swimmer performed two
maximal 50-m freestyle time trials with a dive start with a 10 min passive break in between
trials. During trials, the audience consisted of two other swimmers, the coach and
performance analyst, no encouragement or feedback was provided. Trials were swum
individually to avoid the influence of other swimmers and recorded via a video with the use
of a 50 Hz Sony digital camera (TRV950 – Sony Corporation, Tokyo Japan) and with
electronic timing. The following measurements were recorded during each effort: time,
velocity and drop off between the first and last 25-m. Velocity was calculated with the use of
GreenEye Race Analysis (Version 4.8.550 – Belconnen, ACT, Australia), a program used to
analyze race performance. The within-swimmer time trial coefficient of variation was 0.9%.

Timed dive starts (Day 2, 2 - 4PM)
In a 50-m pool after an individualized warm up, swimmers performed two sets of three dive starts with a 5 min rest period between sets, no feedback or encouragement was given. A kicker was in place on the starting block. Participants were instructed to perform the start as they would in a competition and swim maximally to the 20 m mark. Electronic timing was used to signify the start for the swimmer and also trigger the capture of two synchronized 50 Hz Sony digital cameras (TRV950 – Sony Corporation, Tokyo Japan). The cameras were placed in the sagittal plane, one above and one below the water and mounted on a purpose-built trolley and rig. The following measurements were collected: mean acceleration, mean power per kg, peak power per kg, velocity off the block and time to 5-m and 15-m.

Statistical Analysis

Traditional statistical methods and magnitude-based inferences (standardized effects) were employed (17) in a single group pre-post intervention design. The dependent measures were swimming time trial performance (over 50-m), dive start and swim-bench power generation. The independent measure was the implementation of a targeted dry-land resistance training program. All numeric values were log-transformed prior to analysis to normalize the data and reduce the homogeneity of error. Measures of centrality and spread are reported as mean ± standard deviation. Precision of estimation was made with 90% confidence limits. Magnitudes of correlation were classified using the following criteria: $r = \pm 0.1$ trivial, $\pm 0.1$-0.3 small, $\pm 0.3$-0.5 moderate, $\pm 0.5$-0.7 large, $\pm 0.7$-0.9 very large, and $\geq \pm 0.9$ nearly perfect. A correlation was deemed unclear if its confidence interval spanned both a substantially positive (0.1) and negative (-0.1) threshold value. A sample size of 10 subjects was required for 80% power to detect a substantial improvement in swimming performance in a single group pre-post design assuming a reference change in time trial performance of 2.1%, a typical test-retest error in performance time of 1.5%, and type I and II errors of 5 and 20%.
respectively. Thus the study was slightly underpowered with only seven international-level Paralympic swimmers as subjects.

RESULTS

Improvements were observed in both the time to 50-m (a decrease of 0.4, ±0.5 s; mean change, ±90% confidence limits) and the swimmers mean velocity over the same distance (1.2, ±1.5 s). A small improvement was also observed in the 1st 25-m time (-1.5%, ±1.5%).

The changes in dive start performance over the 6-week period are presented in Table 1. Swimmers substantially improved their ability to accelerate and produce more power in their dive while decreasing their time to 5-m (-0.1, ±0.1 s; mean, ±90% confidence limits) and 15-m (-0.2, ±0.1 s).

(Figure 1 about here)

(Table 1 about here)

No clear changes were seen on the swim-bench ergometer after the 6-week intervention in either power (-0.6, ±3.7 W; mean, ±90% confidence limits) or force measures (Table 2). Correlations for measures of mean power generated on the swim-bench ergometer and swim velocity over 25-m and 50-m were also unclear. In contrast, there were large increases in power for both the squat jump (139%, ±97%; difference, ±90% confidence limits) and the counter movement (188%, ±181%) jump, and a moderate increase in the mean concentric peak velocity of the squat jump (11%, ±11%).
Over the 6-week training period, no substantial improvements were observed in anthropometric measures. Changes in both the sum of seven skinfolds (-3.7, ±4.0 mm; difference, ±90% confidence limits) and lean mass index (0.3, ±0.4 units) were trivial. At the start of the trial, a large correlation (r=0.72, ±0.42; r-value, ±90% confidence limits) was evident between sum of seven skinfolds (body fat) and swimming velocity. At the end of 6-weeks of resistance training, the magnitude of the relationship were moderate for sum of skinfolds and swimming velocity (r=0.50, ±0.57).

Training-induced improvements in jump test velocities in the gym were associated with higher velocities off the block during dive starts. At baseline, relationships between dive start velocity and mean velocity during both the counter movement (r=0.15, ±0.67; r-value, ±90% confidence limits) and squat jump (r=0.15, ±0.67) tests were trivial and unclear. However, after 6-weeks, the relationships between jump testing and dive start velocity were large (countermovement jump: r=0.56, ±0.54) and very large (squat jump: r=0.78, ±0.37; see Figure 2).

DISCUSSION

This is the first study to quantify the effects of a dry-land intervention program on swimming performance in Paralympic swimmers. The aim was to evaluate the effectiveness of a dry-land program and to determine whether improvements transferred to swimming performance. Over the 6-week period, intensity and volume of the dry-land strength program was systematically varied to improve dive starts, posture, and swimming performance.
Improvements in muscle strength and control were evident in the swimmer’s ability to hold a more stable body position in the water and generate more power in the dive. From these improvements, it appears the transfer of qualities developed in dry-land resistance training can positively influence swimming performance. These results in Paralympic swimmers support previous research in able-bodied swimmers (3, 15, 32) showing that increases in swimming performance are greater in a combined swimming and dry-land strength training program compared with a swim only program.

The higher power and acceleration associated with the dive start suggest that the dry-land program improved the muscle activation sequencing used by the Paralympic swimmers. These improvements enabled the Paralympic swimmers to increase their ability to generate higher velocity in a shorter time period, and complete the movement patterns of the dive faster. The improved times to 5-m and 15-m from timed dive starts are similar in magnitude to the faster times seen in the 50-m time trials. It appears the 6-week dry-land program assisted swimmers in becoming more powerful, and being able to better control their bodies through the dive both under and above water. This finding is contradictory to previous research (4, 6) that found no significant improvements in dive start performance in either a 6 or 8 week resistance training program. It was theorized that this outcome may be due to the specific skills involved in starting and thus improvements in jumping ability might not be transferrable (6). The large and very large relationships seen between jump testing and dive start velocity in the current study suggests the possibility of a commonality between vertical jumping and diving (17, 22). However the contrasting results would suggest otherwise and a proposed explanation for this difference is the different type of dive starts used. The current study did not use the grab, track or swing start but rather the ‘kick’ start. The introduction of an incline or ‘kick’ plate mounted to the start platform in 2009 changed the way swimmers
performed the dive start and quickly became the norm. The ‘kick’ start is a modified track start that allows the rear foot to be raised off the platform and placed upon a kick plate (16).

The tighter coupling of dive start velocity and force-power characteristics of the squat jump movements after the 6-week intervention appears to reflect better transfer and movement control between different exercise tasks. However these results conflict with those of Tanaka et al. (34) who claimed that strength exercises executed in the water are more efficient than dry-land training, after finding no significant improvements in swimming performances between a group that combined regular swim training with strength training and a control group who performed swim training only. However, the attendance at seven competitions during the study period may have eliminated possible benefits of the intervention programme due to overreaching or overtaining. The design of this present study was based on suggestions that exercises in dry-land strength training programs should replicate the movement velocity and joint angle of that in the water (25, 36). In this study, the benefits can be seen in the translation of these adaptations to improved sprint swimming performance with more powerful dive starts leading to faster times to 5-m and 15-m, and ultimately faster 50-m time trial performance.

The 50-m time trial was substantially faster (1.2%, ±1.5%; mean change, ±90% confidence limits) after the 6-week intervention period. These changes are worthwhile when improvements in Paralympic swimming times are considered. Over a Paralympic cycle (4 years) the winning time for the 50-m freestyle improved by ~1.7% (Beijing 2008) and ~2.2% (London 2012), while S14 times for the same event and over a 4 year period increased by ~6.1% (2011 Global Games). The magnitude of these changes implies the implementation of a dry-land resistance training program would be beneficial to improving sprint performance.
and increase the swimmer’s chances of medaling. The magnitude of improvement in performance after a short 6-week period late in the training season, and without a taper, is larger than would be predicted for a swim-only program over the same time period. However these changes are slightly smaller than has been reported with previous studies showing between 1.3% and 4.4% improvements with intervention programs (9, 32). This difference may be due to the subject groups, with studies showing that improvements in swimming performance in Paralympic swimmers do not appear to be as great as able-bodied swimmers. In this cohort of Paralympic swimmers, typical improvements of ~0.5% per year have been reported (12) while in a previous study on able-bodied swimmers (1), that investigated seasonal changes in sub-maximal and maximal velocity, the performance of male swimmers improved by 1.5% (95% confidence limits ±1.0%) and females by 2.2%. The intervention here was completed 4 weeks prior to the selection trials, which is the beginning of the international season. It appears that over a short period at a critical time of a season that substantial improvements in strength, power and sprint swimming performance can be obtained in Paralympic swimmers.

In general the Paralympic swimmers who generated greater mean power on the swim-bench swam faster in the 50-m trial. However there was substantial variability between individual swimmers, and this relationship was smaller than has been reported in previous studies. In 21 Paralympic swimmers, a large relationship between mean power and swimming velocity was evident over 100-m (r=0.53, ±0.28; r-value, ±90% confidence limits) (10). Similarly, able-bodied swimmers exhibited a very large relationship (r=0.90) between power production on a swim-bench ergometer and velocity over 25 yards (29). We observed that swimmers with certain disabilities (e.g. cerebral palsy) had difficulty in completing the maximal effort 60 sec
swim-bench protocol. Future investigators might consider employing a shorter protocol (30 sec) to reduce the possibility of some swimmers being disadvantaged.

**PRACTICAL APPLICATIONS**

Dry-land exercises that target specific motor skill and coordination relevant to Paralympic swimming can improve strength, power, dive starts and free swimming velocity. Despite the large variation in disabilities being a fact of life in Paralympic swimming, this study showed that a generalized program over a 6-week period can elicit improvements in Paralympic swimmers that are transferrable to swimming performance. A dry-land resistance training program that is more individualized in regards to the particular exercises prescribed on a swimmer-to-swimmer basis depending on their underlying disability may elicit greater improvements.

To complement dive start testing and training, it would be beneficial to incorporate a squat jump with concentric only movement given it is closely associated with swimming, as there is no leg-orientated counter-movement involved during starts or turns. This adaptation should translate to improvements in the pool and enable strength and conditioning coaches to track improvements in power generation. Swim bench testing however appears less useful in monitoring the effects of short-term training.

Coaches and swimmers are encouraged to undertake continuous dry-land training programs throughout the season. This approach should enable the development of the upper body for increases in propulsion through the water, strengthening of the shoulder girdle to reduce risk of injury, an increase in strength and power of the lower body to improve velocity generation...
during the dive start, and better activation and core of the core muscle to maintain body position in the water to minimize drag.
REFERENCES


Acknowledgements

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Figure Legends

Figure 1. Change in 50-m time trial performance after a 6-week dry-land training intervention program (mean, ±90% confidence limits)

Figure 2. Magnitude of relationship between dry-land jump testing and pool-based dive starts pre and post, 6-week dry-land training intervention program (r-value, ±90% confidence limits)

Table 1. Change in swimming-specific performance measures, drag and power in Paralympic swimmers after a 6-week dry-land training program (mean, ±90% confidence limits)

Table 2. Change in strength and power measures in Paralympic swimmers after a 6-week dry-land training program (mean, ±90% confidence limits)
Table 1. Change in swimming-specific performance measures and power in Paralympic swimmers (n=7) after a 6-week dry-land training program (mean, ±90% confidence limits)

<table>
<thead>
<tr>
<th></th>
<th>50-m Time (s)</th>
<th>1st 25-m Time (s)</th>
<th>2nd 25-m Time (s)</th>
<th>Drop Off (s)</th>
<th>Velocity (m.s(^{-1}))</th>
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</thead>
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<tr>
<td><strong>Mean ± SD</strong></td>
<td>-0.4 ± 0.5</td>
<td>-0.3 ± 0.2</td>
<td>-0.1 ± 0.3</td>
<td>0.1 ± 0.3</td>
<td>0.02 ± 0.02</td>
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<td>-1.2%, ±1.5%</td>
<td>-1.5%, ±1.5%</td>
<td>-0.9%, ±1.9%</td>
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<td>1.2%, ±1.5%</td>
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<td>Unclear</td>
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<table>
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<tr>
<th></th>
<th>Velocity (m.s(^{-1}))</th>
<th>Mean Acceleration (m.s(^{-2}))</th>
<th>Mean Power/kg (W)</th>
<th>Peak Power/kg (W)</th>
<th>Time to 5-m (s)</th>
<th>Time to 15-m (s)</th>
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<tbody>
<tr>
<td><strong>Mean ± SD</strong></td>
<td>-0.01 ± 0.09</td>
<td>0.17 ± 0.17</td>
<td>0.8 ± 0.7</td>
<td>1.6 ± 2.2</td>
<td>-0.1 ± 0.1</td>
<td>-0.2 ± 0.1</td>
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<td><strong>Percentage Change</strong></td>
<td>-0.2%, ±2.4%</td>
<td>3.7%, ±3.7%</td>
<td>6.1%, ±5.9%</td>
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<td>Moderate</td>
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Table 2. Changes in strength and power measures in Paralympic swimmers (n=7) after a 6-week dry-land training program (mean, ±90% confidence limits).

<table>
<thead>
<tr>
<th></th>
<th>Concentric Only Movement Average Mean Power (W)</th>
<th>Concentric Only Movement Average Peak Velocity (m.s(^{-1}))</th>
<th>Counter Movement Average Mean Power (W)</th>
<th>Counter Movement Average Peak Velocity (m.s(^{-1}))</th>
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</thead>
<tbody>
<tr>
<td><strong>Mean ± SD</strong></td>
<td>139 ± 97</td>
<td>0.3 ± 0.3</td>
<td>188 ± 181</td>
<td>0.2 ± 0.1</td>
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<td><strong>Percentage Change</strong></td>
<td>12%, ±9%</td>
<td>11%, ±11%</td>
<td>15%, ±14%</td>
<td>6.6%, ±6.4%</td>
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<td>Moderate</td>
<td>Small</td>
<td>Small</td>
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<tr>
<td><strong>Mean Force (N)</strong></td>
<td>0.1 ± 4.6</td>
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Figure 1. Change in 50-m time trial performance after a 6-week dry-land training intervention program (mean, ±90% confidence limits)

* = Small change
Figure 2. Magnitude of relationship between dry-land jump testing and pool-based dive starts pre and post, 6-week dry-land training intervention program (r-value, ±90% confidence limits)