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Title: **Effect of traditional and resisted sprint training in highly-trained, female team handball players**

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Running Head: Sprint Training in Team Handball

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Abstract

Fast acceleration is an important performance factor in handball. In addition to traditional sprint training (TST), resisted sprint training (RST) is a method often used to improve acceleration. However, studies on RST show conflicting results, and underlying mechanisms are not studied. **Purpose:** To compare the effects of RST, by sled towing, against traditional sprint training on sprint performance and muscle architecture. **Methods:** Participants (n=18) were assigned to either RST or TST and completed two training sessions of RST or TST per week (10 weeks), in addition to their normal team training. Sprint-tests (10-m and 30-m) and measurements of muscle architecture were performed pre- and post-training. **Results:** Beneficial effects were found in the 30-m sprint test (mean; ±90% CL) for both groups (TST=-0.31; ±0.19 s, RST=-0.16; ±0.13 s), with unclear differences between the groups. Only TST had a beneficial effect on 10-m time (-0.04; ±0.04 s), with a likely difference between the two groups (85 %, ES= 0.60). Both groups had a decrease in pennation angle (-6.0; ±3.3% for TST and -2.8; ±2.0% for RST), which had a nearly perfect correlation with percentage change in 10-m sprint performance (r=0.92). A small increase in fascicle length (5.3; ±3.9% and 4.0; ±2.1% for TST and RST, respectively) was found, with unclear differences between groups. **Discussion:** TST appears to be more effective than RST in enhancing 10-m sprint time. Both groups showed similar effects in 30-m sprint time. A similar, yet small, effect of sprint training on muscle architecture was observed in both groups.

Key Words: muscle architecture, acceleration, team sports, pennation angle,

Introduction

There are many factors that are important for performance in handball, such as technical and tactical aspects, and to fully exploit these qualities there is a need for superior physical conditioning. Time motion analysis show that handball players spend a low amount of time in running velocities defined as sprinting.[1] This may be due to the small effective playing area in handball, that does not allow players to achieve maximum speed.[2] Despite the low amount of time spent in speeds defined as sprinting, there seems to be no doubt that handball requires high intensity actions and sprinting efforts.[1,3] Consequently, the acceleration phase of a sprint is likely to have a greater importance than maximal speed for performance in handball.

In addition to traditional sprint training (TST), strength and conditioning researchers have focused on resisted sprint training (RST) as a training method to improve acceleration.[4] The objective of RST is to create an overload, and thus to elicit a greater neuromuscular activation and to enhance the recruitment of fast twitch-fibers.[5] Furthermore, increasing the force output of the knee and hip extensors has previously been suggested to be a beneficial outcome of RST.[5] Sled towing is one of the methods used for RST. Investigation of the acute effect on sled towing suggests that approximately 12.5% of body mass results in minimal disruption to sprint kinematics, while still providing an overload stimulus to the involved musculature.[4] To date, the published research has shown conflicting results[2,6–8] regarding the effectiveness of RST on sprint performance. For example, West et al.[2] compared RST (sled towing) versus TST for 6 weeks in the pre-season period for a group of professional rugby players, on performance of 10-m and 30-m sprints, and reported improvements for both groups. However, the improvements for the RST group were greater than for the TST group (0.04 ± 0.01 s; 10-m and 0.10 ± 0.03 s; 30-m for RST versus 0.02 ± 0.01 s; 10-m and 0.05 ± 0.03 s; 30-m for TST). Conversely, Clark et al.[8] did not find RST (sled towing) to be as effective as TST on sprint performance. After 7 weeks of training in male collegiate lacrosse players, RST only had trivial effects on sprint time (-0.13%), while TST had a small effect (-1.09%). However, in this study the sprint distance was longer (measured from approximately 18 m to 55 m). Thus, as previously suggested, TST and RST may both improve sprint performance, but at shorter distances (5-10 m) RST may provide a superior training stimulus.[2,9]

While the previous investigations on this topic have focused on the performance outcomes, the underlying mechanisms for these changes are missing. Therefore, it seems critical to investigate some of the likely mechanisms for these adaptions. It has previously been suggested that muscle architecture can explain more variance for strength and velocity than intrinsic chemical properties.[10] Indeed, the size and relative arrangement of fibre bundles – fascicles – and their aponeuroses determine the mechanical output of pennate muscles[11]. Ultrasound-based measurements of this arrangement can be reliably obtained in the *m.* vastus lateralis *in vivo*[12] and correlate well with sprint performance, both for male and female athletes.[13,14] In addition, it is shown that there are significant differences in pennation angle in *m.* vastus lateralis between sprinters and long distance runners[15]. It is also been shown that muscle architecture demonstrate adaptions in response to training,[16,17] especially after resistance training. Longitudinal research regarding muscle architecture changes following sprint training and resisted sprint training is currently sparse.

The purpose of this study is to compare the effects of sled towing RST against TST in a group of semi-professional handball players on sprint performance, and to investigate whether these effects were reflected in muscle architectural measurements.

Method

One team of semi-professional female handball players (n=24) were recruited for the study. The team played in the first division in Norway. To ensure that the data reflects the effect of the intervention, the participants had to complete at least 80% of the intervention training sessions. As a consequence, six participants were excluded from the analysis. This study is thereby based on 18 participants. The duration of the intervention was 10 weeks, commenced in the latter portion of the preseason period (3 weeks before first official match) and was completed in the in-season period. Participants were assigned to two different groups; RST group (age 20.4 ± 3.1 y, stature 170.3 ± 5.3 cm, body mass 74.6 ± 5.9 kg) or TST group (age 23.1 ± 3.9 y, stature 172.0 ± 6.4 cm, body mass 69.9 ± 5.3 kg) based on their 10-m sprint time.[2] Throughout the duration of the study, all of the participants engaged in regular team practices, consisting of specific technical and tactical drills (3 sessions per week), matches (on average 1 per week) and the specific sprint training (2 sessions per week). The participants were accustomed to strength training, however the participants did not undertake strength training during the intervention. The training load throughout the study was monitored with sessional Rating of Perceived Exertion (sRPE).[18] There was no substantial between group differences in sRPE (data not reported). Participants gave their written informed consent and declaration of health before the start of the study. The goalkeepers were included in the material, as they had a similar response as the field players in this study. There was one goalkeeper in each of the two groups.

Experimental Procedures

Before the start of the intervention all participants completed baseline testing with a 30-m sprint test (with 10-m split time), The test was performed twice within 6-9 days, in order to determine the typical error for this specific population (table 1). As a part of the baseline testing the participants also performed ultrasound measurements on a separate day. Typical error data for the ultrasound measurements were obtained by repeated measurements of 11 moderately trained individuals not participating in the study.

INSERT TABLE 1 HERE

The participants had a light training day (standardized group training) on the day before testing. The sprint test was performed on a flat, indoor surface (PULASTIC SP Combi, Gulv og Takteknikk AS, Norway). A standardized warm-up drill, consisting of a 10-min jog and 5 min of movement specific drills was conducted. After the warm-up the participants completed 3 x 30-m sprints (2 min rest between trials) from a stationary start (30 cm behind the start line), using a split stance.[19] Electronic timing gates (Speed Trap II TC Wireless Timing System, Brower) were placed at the start line and at 10 m and 30 m from the first set of gates. The mean of the best two attempts was used in the analysis.

B-mode ultrasound measurements were performed on *m.* vastus lateralis in the right leg of all participants, using a linear array transducer (50 mm, 5-12 MHz, HD11XE, Phillips, Bothell, Washington, USA). The measurements were performed while the participants were lying supine and instructed to be fully relaxed. Measurements were taken at 60% of the distance from the greater trochanter to the lateral epicondyle of the femur. Three pictures were taken for muscle thickness and three for pennation angle, all pictures were analysed (ImageJ, Rasband, W.S, National Institute of Health, Maryland, USA) three times and the mean value was used in further analysis. The ultrasound measurements were performed by one single tester[12] (typical error is stated in table 1). Fascicle length was calculated with simple trigonometry (T/sin(3.14*θ/180) where θ is the pennation angle and T is the muscle thickness. All testing procedures were replicated for the post-testing session.

Training

Both training groups completed their respective programmes twice a week for a 10-week period, except for week 6 and 10 when one weekly session was completed for both groups (total of 18 sessions). Training took place on Mondays and Thursdays, late afternoon, for both groups, on the same surface as the testing sessions. Before each session the participants completed a standardized warm-up routine, consisting of 5 min jogging, 5 min ball play and 5 min movement specific drills. Both groups completed the same amount of sprints and distance. Detailed information on the training is given in table 2. The RST group performed all the sprints with an additional weight of 12.4 ± 0.2%, similar to previously studies[4] of body mass, connected to a sled. The sled was connected to the participants by a waist belt. The participants were instructed to give maximal effort in each sprint.

INSERT TABLE 2 HERE

Statistical analyses

Data from pre- and post-tests are presented as mean ± SD. Data for changes are presented as mean; ±90% confidence limits (CL), both for raw data and percentage data. The percentage data shown are log transformed. Differences between pre- and post-test for both groups, and differences between the two groups were analysed on log transformed data using Cohen´s effect size (ES) statistics and ±90% CL. ESs of <0.2, 0.2 to 0.6, 0.6 to 1.2, 1.2 to 2.0 and >2.0 were considered trivial, small, moderate, large and very large, respectively.[20] The percentage likelihood of difference between groups was calculated and considered almost certainly not (<0.5%), very unlikely (<0.5%), unlikely (<25%), possibly (25-75%), likely (>75%), very likely (>99%), or almost certainly (>99.5%). Threshold chances of 5% for substantial magnitudes were used, meaning likelihood with >5% in both positive and negative manner was considered an unclear difference. Correlations of change in sprint performance and change in muscle fascicle length and change in pennation angle were assessed by Pearson product-moment correlation coefficient. Magnitude of effect for the correlations were based on the following scale: <0.10 trivial, 0.10-0.29 small, 0.30-0.49 moderate, 0.50-0.69 large, 0.70-0.89 very large, and >0.90 nearly perfect.[20]

Results

Performance

The performance data from the pre- and post-tests are presented in table 3, along with percentage change and effect size. For the 10-m sprint time between groups comparison, a likely (85%) difference in favour the TST group (ES= 0.60) was evident. Both training groups had a positive change in performance for 30-m with unclear differences (ES= 0.85) between groups.

INSERT TABLE 3 HERE

Muscle architecture

The pre- and post-measurements of muscle architectural characteristics, changes, and effect sizes are presented in table 4. The between groups comparison of changes in pennation angle showed a possible (62%) difference between the two groups (ES= 0.25). The difference in fascicle length between the two groups was unclear (ES= 0.09). Percentage changes in pennation angle, for both groups combined, had an almost perfect correlation with percentage changes in 10-m sprint time (r=0.92; figure 2); however, a similar correlation was not found for pennation angle and 30-m sprint time (r=0.07). Percentage changes in fascicle length had a correlation of -0.51 and -0.21 for percentage change in performance in 10-m and 30-m sprint, respectively.

INSERT TABLE 4 AND FIGURE 1 HERE

Discussion

The main results from this his study showed an unclear difference between TST and RST for 30-m sprint time and a likely difference in favour of the TST group on 10-m sprint time. Pennation angle in *m.* vastus lateralis decreased in both groups and a nearly perfect correlation between changes in pennation angle and changes in 10-m sprint performance was observed. Fascicle length increased in both groups. We do acknowledge the possible contribution of other training factors, as the participants concurrently trained handball. However, all training factors (e.g. training mode, training load, exercises and intensities) were consistent for both groups in this study, and should thereby not influence the differences between the two groups.

The 0.31-s improvement of the TST group on 30-m sprint time is, compared to other studies, large in magnitude. Studies of sprint training in handball are lacking, however previous research in soccer and rugby has shown improvements of 0.06 - 0.13 s in sprints over 30-40 m.[2,6,21] Less experience with physical conditioning provides more potential for stimulating positive effects [22]. Even though the participants in this study were well-trained handball players, it is proposed by others that well-trained team-sport athletes can be considered untrained in terms of sprint training,[22] because the nature of the daily training may not include sprint training as a major focus. It is also a possibility that because of the natural decline in training load as the season commenced; the improvements are somewhat higher than that found in other studies.

The training effect on 30-m time for RST was moderate, while for the TST it was large, however there was no clear difference between the groups on this variable. Conversely, a likely difference in favour of TST was observed for 10-m sprint time. All changes of sprint times were outside of the typical error of measurement, with exception of the 10-m sprint time for RST. This is in contrast with previous studies, suggesting that sled towing may provide a superior training stimulus for sprints over shorter distances.[2,7,9] West et al.[2] found RST to have a more pronounced effect than TST and suggested that others, who have not found RST to be more effective, used too light load (e.g. Clark et al.[8] who used 10% of body mass). West et al.[2] used a load of 12.6% of body mass, which is very similar to 12.4% used in this study, thus the load used is not the only factor explaining the conflicting results regarding RST. However, depending on the resistance of the floor, the friction, and thus the resistance may vary regardless of the load. This is, unfortunately, not taken into consideration in the previously mentioned studies,[2,4,8] nor the present study. This makes it more difficult to compare the loading scheme between studies. The recommendation of loading in RST is based on kinematic measurements of male subjects.[4] It is conceivable that female subjects do not have the same optimal load relative to body mass as males, due to sex differences in muscle mass and maximal muscle strength. Thus, it can be speculated that optimal load for RST should not be described dependent on body mass alone. Measures of strength, muscle mass, decrement in sprint velocity with the external load or other variables might be more applicable when determining the load of RST. However, this needs to be investigated further. Other studies[23] have shown that there are no differences in the effects of RST with high or low loads. This indicates that there are several factors that play a role in the effectiveness of RST, and this should be addressed in the future.

It is previously suggested that resistance training with low load and high velocity may be superior to high load and low velocity in terms of power-output and velocity.[24] The horizontal speed in RST will be reduced with an increase in load[4] and thereby influence the velocity of muscle contractions. This could possibly hinder specific high-speed adaptions in the musculature.[25] RST acutely leads to lower sprint velocity and the slower speed might not be specific enough to develop acceleration skills in sprints, and may account for some of the observed changes in this study. On the other hand, external loading has hypertrophic effects in the musculature, even at relatively low loads[26] and can thereby be beneficial for force output. The loading used in the current study is regarded as relatively high[4,23,27] for sled towing involving field sport athletes. However, we did not find changes in muscle thickness in this study for the RST group (or the TST group). This suggests that the loading or the volume of loaded sprints, used in our protocol, may have been insufficient, relative to the subjects' strength, to induce the expected hypertrophic response

The exact mechanism(s) that can account for training effects of RST and TST are still unclear. It has previously been shown that there is a significant negative relationship between sprint time and fascicle length, in both male and female athletes.[13] Furthermore, research on muscle architectural changes has shown that specific training regimes can evoke changes in muscle thickness, pennation angle and in fascicle length.[16,17,28] It is also reported that a decrease in pennation angle can occur, after a period of sprint/jump traning.[17] In this study, both RST and TST had a change in fascicle length, with a lengthening of 4-5%, and a decrease in pennation angle. The decrease in pennation angle showed a nearly perfect correlation with change in 10-m sprint time. To our knowledge, this is the first study to investigate and demonstrate architectural changes to sprint training. Although, the sample size is small, the magnitudes of the observed changes in fascicle length and pennation angle are greater than the typical error calculated for these variables. Although the external validity of these results should be strengthened with future studies on larger sample populations, we believe that these data reflect genuine muscular adaptations.

The force-velocity relationship of muscle fibres can explain the fascicle length influence on sprint performance. The shortening velocity of longer fibers (with more sarcomeres in series) is higher than in shorter fibers. In addition, longer muscle fibers will exert more force at any given velocity than shorter fibers with the same thickness, as the sarcomeres could be at lengths closer to their optimal force-production. As a result, the increase in fascicular length observed in the present study may have enhanced sprint performance by favouring a larger power output of the knee extensor muscles. Another possibility to explain the present gains in performance lies in the changes in pennation angle. The contraction velocity of pennate muscles can exceed that of its fibres by virtue of their rotation about the muscle line of action.[29] The effects of training upon the ratio of fibre- to muscle velocity are unknown and the present study was not designed to measure this parameter. However, the observed decreases in pennation angle suggest that a larger fibre rotation was enabled in the *m.* vastus lateralis, favouring a higher contraction velocity. The strong correlation between post-training changes in pennation angle and 10-m sprint performance supports this hypothesis but further research focused on the above architectural parameters is required. The lack of correlation between changes in 30-m sprint and in pennation angle is likely attributable to the relative contribution of knee extensor muscles declining after the first 15 m of sprinting.[30] It would therefore be of interest to investigate the effect of sprint training on muscle architectural changes of the hip extensor muscles in the future, to see if longer sprint distances could affect this.

The change in muscle thickness is less than the typical error of measurement, and can thereby not be acknowledged as a true change. Abe et al. (2000)[15] found that differences in muscle thickness between sprinters and untrained are more pronounced at 30% and 50% of thigh length, with no difference between the groups found at 70%. In the current study, the participants were measured only at 60%, and thereby this may not reflect the true changes in whole length of the muscle.

Only one resistance load was investigated in this study. Further studies with a variation in the loading between groups could provide a greater insight into the loadings effects on muscle architecture, and should be conducted in the future. Also, the loading could be prescribed by other variables than percentage of body weight, for example by percentage decrementing of sprint time.[23]

Practical applications

The findings of the current study have practical implications for female handball players and may assist coaches in training program design for sprinting. The study shows that while there was no meaningful difference in the effects of the two interventions on 30-m sprint time, only TST had a beneficial effect on 10-m sprint time. This is a more important performance variable than the 30-m, as 10-m sprints are likely to occur more often than 30-m sprints in handball.

Conclusion

In conclusion, our results indicate that TST training is more effective in enhancing performance in short distance sprints (10-m) than RST, while there was no difference between the two groups in effect on 30-m sprint time. A change in fascicle length was observed for both groups, and studies investigating the effect of sprint training on changes in muscle architecture should be conducted in the future.

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Table(s):

Table 1: Measurements of typical error (expressed as coefficient of variation; %CV) for the field tests and muscle architectural variables. Both raw data and percentage data are shown, with upper and lower 90 % CL.

		Raw data			%CV		
		Typical error	Lower 90 % CL	Upper 90 % CL	Typical error	Lower 90 % CL	Upper 90 % CL
Field tests	(n=19)						
10 m (s)		0.03	0.03	0.05	1.6	1.2	2.2
30 m (s)		0.05	0.04	0.07	1.0	0.8	1.5
Muscle architecture	(n=11)						
Muscle thickness (cm)		0.05	0.01	0.06	2.0	-0.6	2.8
Pennation angle (°)		0.13	-1.0	0.1	1.0	0.9	1.0
Fascicle length (cm)		0.16	-1.0	0.2	2.7	0.9	1.0

Table 2: Summary of training content in the intervention period. Training is listed as: number of sets x number of sprints in one set x distance of each sprint. Total time per session excludes warm-up.

Week	Training		Total distance (per session)	Total time (per session)
1-4	4x3x20 m Rest: 2 min Active recovery: 5 min		240 m	35 min
5-9	3x3x20 m Rest: 2 min Active recovery: 5 min	2x5x10m Rest: 1.5 min Active recovery: 5 min	280 m	44 min
10	4x3x20 m Rest: 2 min Active recovery: 5 min		240 m	35 min

Table 3: Pre-test and post-test performance measurements (mean ± SD) and changes in the 10-m and 30-m sprint test.

		Performance (mean ± SD)		Change in performance (mean ±90 % CL)		Magnitude of differences	
		Pre-test	Post-test	Raw data	%	Effect size	Rating
10 m (s)							
TST	(n=8)	2.01 ± 0.07	1.97 ± 0.07	-0.04 ± 0.04	-1.9 ±2.0	0.51	Small
RST	(n=10)	2.01 ± 0.06	2.01 ± 0.06	-0.01 ± 0.02	-0.3 ±1.1	0.08	Trivial
30 m (s)							
TST	(n=8)	4.77 ± 0.18	4.46 ± 0.26	-0.31 ± 0.19	-6.6 ±4.0	1.56	Large
RST	(n=10)	4.81 ± 0.17	4.65 ± 0.31	-0.16 ± 0.13	-3.5 ±2.8	0.93	Moderate

Table 4: Pre- and post-measurements of muscle thickness, pennation angle and fascicle length

		Muscle architecture (mean ± SD)		Change in muscle architecture (mean ±90 % CL)		Magnitude of differences	
		Pre	Post	Raw data	%	Effect size	Rating
Muscle thickness (cm)							
TST	(n=6)	2.39 ± 0.30	2.37 ± 0.31	-0.03 ± 0.06	-1.1 ±2.6	0.07	Trivial
RST	(n=8)	2.34 ± 0.24	2.37 ± 0.26	0.03 ± 0.05	1.2 ±2.0	0.10	Trivial
Pennation Angle (°)							
TST	(n=6)	18.3 ± 2.5	17.3 ± 3.0	-1.0 ± 0.6	-6.0 ±3.3	0.38	Small
RST	(n=8)	17.8 ± 2.5	17.3 ± 2.1	-0.5 ± 0.4	-2.8 ±2.0	0.19	Trivial
Fasicle length (cm)							
TST	(n=6)	7.7 ± 1.3	8.1 ± 1.3	0.4 ± 0.3	5.3 ±3.9	0.26	Small
RST	(n=8)	7.7 ± 0.6	8.0 ± 0.5	0.3 ± 0.1	4.0 ±2.1	0.46	Small

Figure(s):

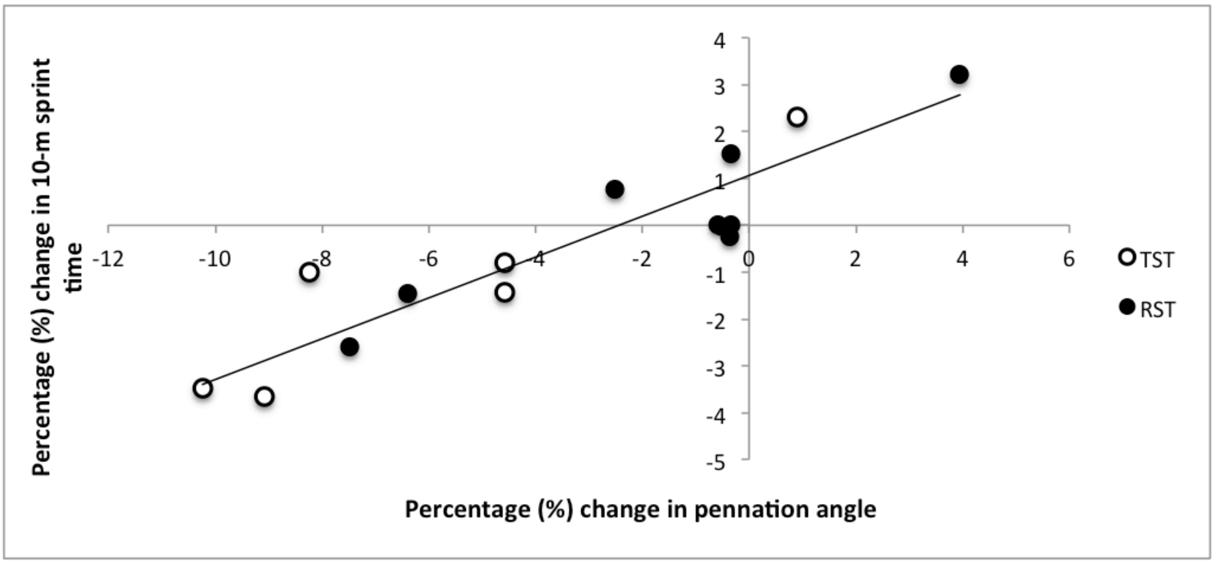

Figure 1: Relationship between percentage changes in 10-m sprint time and percentage changes in pennation angle.