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Effect of Specific Resistance Training on Overarm Throwing Performance

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Purpose: The main purpose of this study was to compare the effect of a specific resistance training program (throwing movement with a pulley device) with the effect of regular training (throwing with regular balls) on overarm throwing velocity under various conditions. ***Methods:*** The training forms were matched for total training load, ie, impulse generated on the ball or pulley device. Both training groups (resistance training n = 7 and regular training n = 6) consisted of women team handball players, and trained 3 times per week for 8 weeks, according to an assigned training program alongside their normal handball training. ***Results:*** An increase in throwing velocity with normal balls after the training period was observed for both groups ($P = .014$), as well as throwing with heavier balls and throwing like actions in the pulley device. Although the regular training group seemed to improve more (6.1%) in throwing velocity with normal balls than the resistance training group (1.4%), this difference was not statistically significant. ***Conclusions:*** These findings indicate that resistance training does not surpass standard throwing training in improvement of overarm throwing velocity.

Keywords: explosive movement, upper extremity, resistance, speed

Through both muscle hypertrophy and neural adaptations, the force-generating ability of muscle increases by strength training, also called *resistance training*.[1] Strength is often an important parameter in sport performance, in particular during explosive actions. Overarm throwing is a typical example of an explosive action where both speed and strength play an important role. Kaneko's classic studies[1,2] show that not only strength, but also maximum movement speed may improve as a result of resistance training, the amount of which depends on the training conditions. Thus, to improve overarm throwing performance, in accordance with Kaneko's studies, different training forms can be categorized according to the principles of overload by resistance or by velocity of the exercise.[3] In overarm throwing sports like baseball, cricket, javelin, and team handball, general resistance training seems to give positive results on the throwing velocity.[4–14] The basic principle behind this positive effect is thought to lie in the hyperbolic force-velocity relationship of muscle and movement (dictating a trade-off between the speed and force that

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can be produced in one movement). In principle, if the maximal force that one can generated in a movement increases by training (eg, increase in one repetition maximum), the power capacity (ie, the force-velocity product) is enhanced, which would show independent of the given movement speed or movement resistance. Thus, if one becomes stronger, one also will become faster at a given level of force or resistance. One should keep in mind that probably both high velocity—and a high strength capacity (due to a high acceleration in the movement) are of high importance for performance in explosive movements.

In many training studies on complex sporting actions, resistance training is introduced in addition to standard training and compared with controls who do not receive any form of additional training.[4,6,8–10,12] Thus, from these studies, it is difficult to assess what aspect of resistance training causes the positive effect: the training form or added training load?

The main aim of the current study was to compare the effect of specific heavy resistance training with that of additional normal throwing training on the overarm throwing velocity with normal balls. In addition, for the purpose of general theory building, we compared these two training forms on their effects on throwing velocity under 5 conditions; these conditions ranged from throwing light balls (low resistance) to 1 repetition maximum (1RM) of a throwing movement (high resistance). We hypothesized that both groups would improve their throwing velocity due to the additional training. Any significant velocity differences between the groups would indicate the role these specific training methods have on ball velocity. In fact, we investigated if training on a particular movement at 2 positions in the force-velocity domain causes different effects on the throwing velocity at the high-velocity end and the low-velocity end of this domain. This latter issue should be regarded as an extension to Kaneko's[2] findings that has been studied extensively in the literature but usually on relatively simple or even single joints movements,[2,15–18] and therefore may not necessarily be applicable to more complex and whole body movements. Only recently, Neils et al,[16] besides studying bench press and squats, performed such a study on vertical jumping.

Methods

Subjects

Nineteen Norwegian experienced women handball players (age 18.1 ± 2.1 years, mass 64.0 ± 7 kg, height 1.67 ± 0.03 m, and handball experience 10.4 ± 1.6 years) playing in the second to fourth division of the Norwegian national competition participated in this study. None of the subjects had considerable experience with resistance training. During the progression of the study, 6 subjects withdrew from the study because of injury, not related to the experiments (4 subjects) or not being able to attend sufficient additional training sessions (2 subjects). Before participating in this study, the subjects were fully informed about the protocol and informed consent was obtained before all testing, in accordance with the recommendations of local ethical committee and current Norwegian law and regulation. All testing and training were performed during the competitive in-season (January–March).

Experimental Design and Methodology

We performed a randomized controlled study in which we compared 2 groups of high-level (subelite) women team-handball players, matched on their maximum ball throwing velocity, that received different additional training forms (experimental, ie, resistance training, referred to as "resistance training" and control, ie, regular ball throwing, referred to as "regular training") with the same training load (ie, total impulse).

Four subjects dropped out of the study due to an injury or illness (2 in each training group). The injuries were not related to the training protocol. Also 2 other subjects were excluded for the further analysis, since they did not attend all training sessions. Thus 13 subjects were included in the final analysis (6 in the regular training group and 7 in the resistance training group). The occurrence of drop-outs led to a slight imbalance in pretraining performance in both groups. The effects are taken into account in the analysis and discussion.

The training bouts were performed in conjunction with the regular training as to fully allow for transfer of effects of the additional training forms onto overarm throwing performed in the sport. For theory building it is equally interesting to study the effects at other points of the force-velocity domain of the movement.[2,17,19] Therefore, we also tested the training effects on the performance during throwing actions with other resistances than the 2 training resistances. Thus, pre- and posttests were performed on maximal throwing velocity 1) with a javelin ball (circumference 0.3m) having a regular handball weight (0.360 kg), 2) a heavy javelin ball (0.432 kg; +20%), 3) a light javelin ball (0.288 kg; −20%), 4) at 85% of 1RM on a pulley device, and 5) at 1RM on a pulley device. The regular javelin ball weight and the 85% of 1RM were the actual training forms that were compared on their training effects.

Test Protocol

The 1RM test was also required for establishing the resistance training load. After a general warm-up of 15 minutes the 1RM of the overarm throwing movement on a pulley device was tested. The subject stood on a height adjustable platform so that the pulling movement could be performed in the same plane as when performing normal throws (Figure 1). A javelin ball was connected to the pulley device such that the subjects held a ball that felt normal and comfortable. The subjects were instructed to make a normal throwing movement as fast as possible. To ensure that the exercise kinematics were as similar as possible to the ball throwing movements, both feet were kept in contact with the platform at all times. The throwing movement was controlled by an experienced handball trainer to ensure that it was an overarm throwing movement according to what Roberton[20] described as an experienced overarm throwing technique. One series of 3 to 6 repetitions at heavy but clearly submaximal resistance were performed for familiarization. In the 1RM test the weight at the pulley device was increased from attempt to attempt until the subjects could not fulfill the whole throwing movement. The starting position was preset: the shoulder and elbow were fully extended, the pelvis was oriented such that the line between the hip was in the goal direction, the trunk was oriented vertically. The end situation was more variable and depended on the individual technique, but the subjects were instructed to attempt to finish as in a normal throw. This led to approximately the following position: shoulder in 30 degrees forward horizontal flexion, the arm oriented horizontally, the elbow 90 degrees flexed, the forearm vertically upward, the trunk 20 to 30 degrees flexed forward, pelvis rotated 30 to 50 degrees. The subjects were allowed to move all body segments withing the given constrictions and instruction. The pauses between the exercises with the different weights were approximately 2 minutes. An 11% friction component (measured in a calibration test) was added to the measured force. After the 1RM test and 5-minute pause, throwing performance was tested in an overarm throw toward a target at 7-m distance. The subjects performed a standing throw with keeping the front foot on the ground during throwing, simulating a penalty throw in team handball. The instruction was to throw as fast as possible aiming at a 0.5 m × 0.5 m square target at 1.65-m height.[21,22] The subjects threw randomly with the weight adjusted javelin balls light balls (–20%), regular balls and heavy balls (+20%) until 3 target hits were performed for each ball. Only throws that resulted in targets hits were considered for further analysis. Throwing velocity was measured using a 3-dimensional digital video movement analysis system (Qtrac, Qualysis) at a sample rate 240 Hz. Half a hemisphere of the javelin ball was covered with reflective tape to identify the center of the ball. Computation of velocity of the ball was done using a 5-point differential filter.[21,22]

After this test, the performance on the pulley device at 85% of 1RM was tested. The same set up was used as during the 1RM test. A force transducer (Revere transducers, model 363-D3-0, USA) was connected to the pulley device to measure the force production and load during the throwing movement.

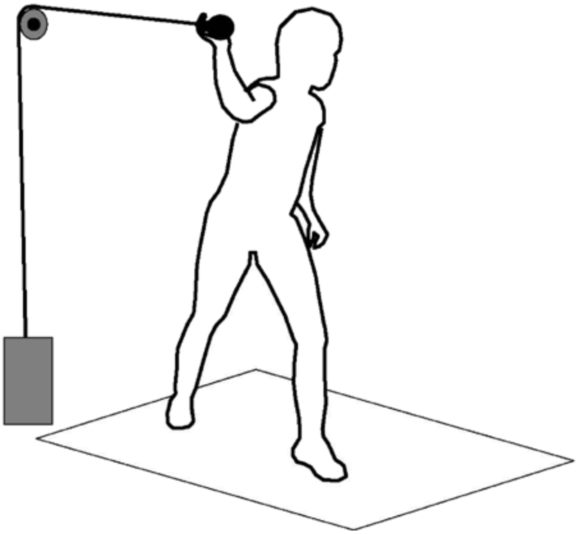

Figure 1 — A throwing movement on the pulley device setup.

Performance for all test conditions, including the 85% of 1RM, but except the 1RM, was measured as the velocity of the object thrown. The 1RM performance was measured as the maximum weight that could be thrown once.

Training Protocol

After the pretests, the subjects were matched on throwing velocity and allocated to the resistance training and regular training groups, accordingly. The regular training group received additional training by throwing (fast) an extra number of handballs and the resistance training group performed bouts on the pulley device mimicking throwing kinematics at 85% of 1RM. The subjects performed these exercises 3 times a week for 8 weeks in addition to the normal training at their clubs. The normal training activities were similar for all subjects and did not contain any resistance training activities. Thus, the additional resistance training was the only form of resistance training the subjects performed during the period of this study. For the regular training group, the only difference between the additional training and throwing exercises in normal training was the sole focus on throwing as fast as possible over a relatively high number of trials (81 throws per session). The training load was measured by the impulse generated per throwing attempt. Impulse ($\int Fdt$) was considered a highly relevant measure for resistance training as it measures the total amount of force produced during the throwing movement. In ball throwing, momentum of the ball at release (mv_{rel}) was used to indicate impulse, as initial momentum was equal to zero ($\int Fdt = mv = mv_{rel}$). As the pulley device was equipped with a load cell the impulse could be obtained directly. The comparison of the pretests revealed the following comparison for the resistance exercises at the pulley device at 85% of 1RM and throwing with regular weighted balls: the resistance exercise resulted in 27.8 Ns versus 6.15 Ns in throwing with the regular weighted balls. Thus, two 1RM repetitions in the resistance training group were matched by 9 standard throws in the regular training group. One training session for the resistance training group consisted of 3 series of 6 repetitions at 85% of 1RM. Thus, the regular training group performed 81 throws per session with regular balls. In both groups these training sessions were exercised in conjunction with their normal team handball practice. As the aim of this study was to compare effects of specific heavy resistance training with additional normal training, and not the absolute effect of training, we did not include a nontraining control group.[23]

Statistical Analyses

To compare the effects of the training protocols on throwing speed, a 2-way ANOVA for repeated measures was used. The test-retest reliability (3 repeats per condition) as indicated by intraclass correlations (ICC) was 0.97 for throwing regular balls, and 0.82 for 85% of 1RM. The effect size and statistical power are presented in Table 1.

Results

In Figure 2 the absolute results of the pre- and posttests are shown for the training exercises and Figure 3 shows the relative training effects for all test exercises. In Table 1, a summary is given of the statistical analysis. The main findings are described below. A significant increase in ball velocity in throwing a standard ball after training was observed. However, no significant differences between the groups were found, indicating that both training forms had similar effects, although a tendency was found for the regular training group to improve more (6.1% vs. 1.4%, *P* = .085). A significant increase in maximal throwing velocity with heavy balls (*P* < .01), at 85% of 1RM (*P* = .029), as well as for 1RM (*P* < .01) was found. Again, no group-training interaction was found (85% of 1RM: 14.3% vs. 9.6%, *P* = .799; 1RM 22.9% vs. 22.7%, *P* = .402, for regular vs. resistance training, respectively), except for heavy balls, where the difference was just significant (7.3% vs. 2.7%, *P* = .05). Throwing velocity with the light balls did not improve significantly (*P* = .115). These results indicate that training effect on throwing velocity, irrespective of training form, increases with the weight of the ball.

Due to the imbalanced pretraining condition, we analyzed the data with regard to pretest performance. Figure 2 indicates that possibly a ceiling effect has occurred for the resistance training group because of their relatively high starting performance. Figure 4 shows the relationship between pretest results and improvement after training for all subjects. No significant correlation was found and no ceiling effect could be detected, neither overall, or within the groups. For example,

Table 1 Statistical Analysis for Training Effects on Throwing Velocity, Both Total and Group Differences

	Training effect on all subjects				Group differences		
Ball	**%**	**P**	**Effect size**	**Stat. Power**	**P**	**Effect size**	**Stat. Power**
Light	2.6	0.115	0.210	0.345	0.090	0.239	0.396
Regular	3.6	0.014	0.439	0.761	0.085	0.245	0.407
Heavy	4.8	<0.01	0.684	0.993	0.050	0.305	0.518
85% of 1RM	11.8	0.029	0.365	0.629	0.799	0.006	0.057
1RM	22.8	<0.01	0.872	1.000	0.402	0.065	0.126

Overall effect is based on the ANOVA's main training effect and group differences on training-group interaction. The percentage (%) column is the pretest to posttest difference expressed as percentage of the pretest value.

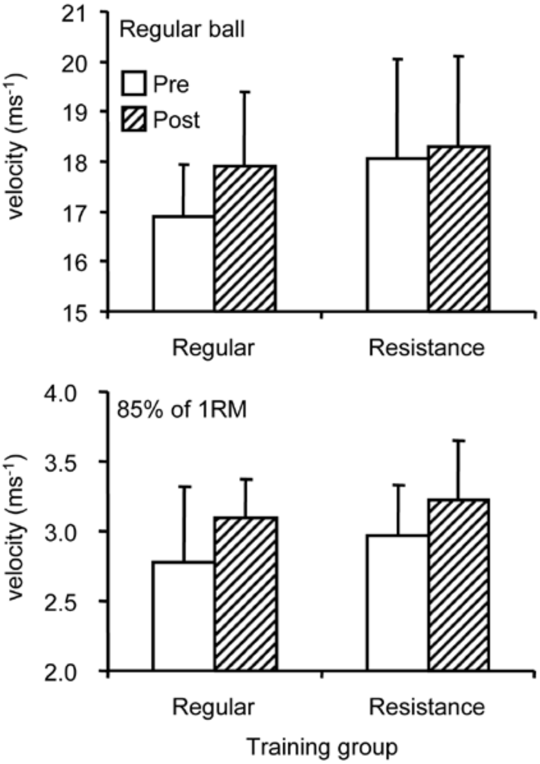

Figure 2 — Throwing velocity for the two training forms, ie, with a regular ball and at 85% of 1RM resistance for both groups at the pre- and posttest. All training effects are statistically significant ($P < .05$) but no group differences for these effects were found.

the subjects with low pretest velocity showed a small training effect, whereas the second fastest subject had a strong improvement. The fastest subject in the resistance training group could be considered an outlier and is the main cause for the pretest imbalance (Figure 4). The main statistical analysis without this subject shows the same findings as the original analysis on all subjects.

Discussion

The most important finding of this study is that specific resistance training does not show a stronger effect than training the performance exercise (in this case throwing regular weighted handballs). Although the pretraining strength level differed in the groups, we have no indication that the results were affected by ceiling effects in the stronger resistance training group. One should also take into account that this initial strength difference was not due to previous resistance training experience. In other words, this study does not confirm the notion that specific resistance training

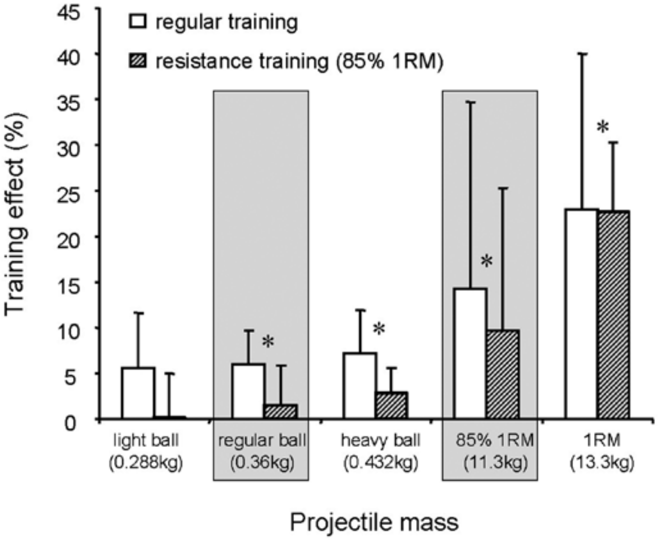

Figure 3 — Training effects for both groups (pre- posttest difference as % of the pretest values) for all tests presented in order of mass to be moved (projectile mass). (*) indicates significant main effect of training ($P < .05$). The gray columns indicate the two training conditions ("85% of 1RM" is resistance training; "regular ball" is regular training). The projectile masses are average and thus indicative only. The 1RM mass is the pretraining mass.

surpasses standard throwing training forms in velocity enhancement in explosive throwing movements.[4,6–10,12] It is however, in accordance with recent data on bench press, squat and jumping,[16] where training at 50% of 1RM tended to show equal or better training results than 80% of 1RM. Due to the low number of subjects (also affected by the dropouts) the statistical power for the group comparison was limited (Table 1). Thus, the lack of group differences should be interpreted with caution. However, the fact that the regular training group improved more than the experimental group in all tasks indicates that probability for that a potential supremacy of the specific resistance training remained unnoticed is rather small. It should be noted that in this study all subjects performed the same regular training alongside the additional training throughout the period. Thus, the transfer of the resistance training effects to handball throwing can be assumed to be uninhibited. At the same time, we cannot draw any conclusions on the component of the training effect that should be attributed to the additional training.

The resistance training exercise was designed to mimic the handball throwing movement as closely as possible. Although we believe we have succeeded in this from a kinematic point of view (but we have no data to confirm this), it does not mean that this also applies to the load at the muscular level. We have no indication if, for example, the trunk and lower extremity was loaded sufficiently to gain the strength effects that are required for improvement of the throwing movement. This may explain the limited performance gain in the resistance training group. Yet, when following this line of argumentation, it becomes difficult to see how, in practice, one can design a highly specific and effective resistance training protocol

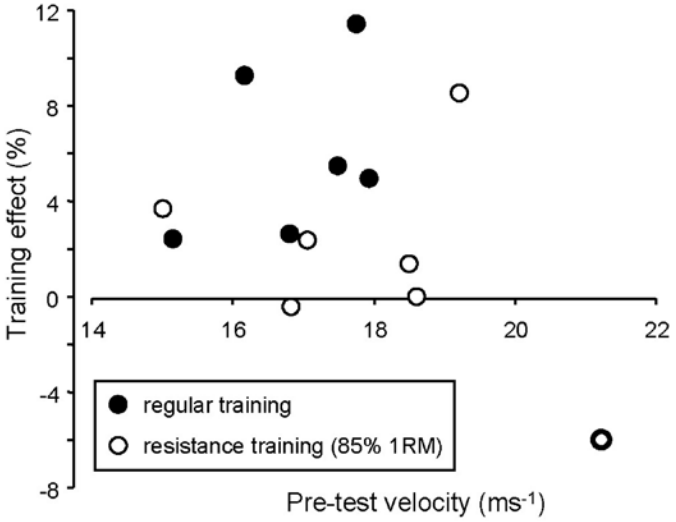

Figure 4 — Training effect on regular balls (%) against pretest throwing velocity of the subjects. No relationship was indicated, especially not if one subject (fat open circle) were considered as outlier (solid circles: regular training group; open circles: resistance training group).

with maximum transfer to actual throwing. Still, an interesting possibility to pursue may be the application of resistance, not only at the most distal segment (as in this study), but also at more proximal segments. From a theoretical perspective, the elucidation is important of which factor may have caused the relatively low training effect for the resistance group, the velocity or the dissimilarity of kinetics. The relatively greater improvements in velocity with the regular training group (although not significant) suggest that adaptations in coordination dynamics may be a more important factor than increases in strength. Thus, changes in coordination (eg, relative temporal patterns among segments and muscle activation patterns) require attention in further analyses. Clearly, more studies including dynamics and muscle activation are needed here.

We attempted to equal the total amount of training load by impulse rather than number of repetitions or duration. We chose for the impulse as measure of training load as a logical relevant factor in resistance training. Of course, it is an issue of debate if this measure is the best one at hand and if it represents the key element of resistance training. We used different methods to estimate impulse in the pulley exercise and ball throwing exercise, which may have led to a systematic error in the comparison. In addition, dictated by the characteristic of the pulley task, the subjects generated an impulse at all times they were holding (resisting) the pulley weight, also after the throwing movement was finished. Only by a subjective evaluation did we conclude that the impulse during the period after the throwing action was of such low intensity that it could hardly have affected the present findings. In anyway, if this evaluation was to be incorrect, it means that we underestimated the training load for the strength training group. On the other hand, as the acceleration of the upper extremity (not just the ball) was higher in regular throwing, the muscle force required to do this must have been higher in the regular throwing exercise compared with the 85% 1RM exercise. In our opinion, such uncertainties in determining the training load should always be kept in mind when drawing conclusions. Another difference between the two training forms may be in the force-time profile (not analyzed here). The similarity in impulse does not mean that both exercises consisted of equal time periods with high forces and moderate forces. It is beyond the scope of this study to compare effects of high force generation for a short time with those of moderate force generation over a long time. However, this issue clearly is highly relevant in the field of strength training. In any case, the load matching procedure in this study led to considerable fewer repetitions for resistance training than additional normal training. Despite the few repetitions needed in resistance training, we are inclined to conclude that specific resistance training is not superior to normal training. Yet, using the same line of thought, one advantageous aspect of specific resistance training becomes obvious. Because of the high load per repetition, a relatively low number of repetitions, and thus training time, is required to obtain training effects.

The significant increase in 1RM for both groups, in particular for the regular training group, may seem surprising at first hand. However, this finding can be explained as follows. Kaneko et al[2] showed that training with lighter weights also increases performances with heavier weights resulting in an increase of 1RM. In our study, both groups trained the throwing movement at a higher velocity than 1RM. Thus, the training transfer in this study to higher resistance-lower speed conditions is in agreement with findings by Kaneko et al.[2] This supports the notion mentioned earlier that, on the one hand, the high speed movements entails an important coordination component that is not trained at low speed-high resistance exercises, and that, on the other hand, the high speed exercises do affect the strength component that is required in the low speed-high resistance action. Furthermore, it should be noted that the peak forces generated at maximal handball throwing approaches those found at the 85% of 1RM exercise (about 180 N), i.e., between 100 N and 150 N.[21] In other words, also the maximal and fast throwing entails a clear strength component. This may apply more generally, i.e., that high speed actions should not be thought of as pure and only opposite actions of high resistance training: if a small or moderate mass is accelerated fast, a considerable force needs to be generated, be it over a short time. This may well lead to considerable strength gains. The order in improvement from 23% in 1RM to an insignificant 2% with throwing light balls (Figure 3) is noteworthy. This may indicate a fundamental issue in adaptation to training, i.e., that in an explosive movement the speed component is more difficult to improve than the strength component. These results are in accordance with, for example, Andersen et al[19] and Toji and Kaneko[17] showing that (variable) resistance training increases strength more than maximal velocity of movement. In addition, Kristensen et al[23] found that the transfer of training to a slower (more resistance) version of the same movement exceeds the transfer to a faster version. All these findings fit the notion that strength adaptation of skeletal muscle to training, that is, hypertrophy and neural drive, is easier to establish than speed adaptation, that is, change in muscle fiber type expression[19,24] or increase of number of sarcomeres in series in a fiber.

Practical Applications

In this study, no evidence was found for the notion that specific high resistance training is an important aspect for improvement of throwing speed in a relatively short training period. This conclusion is based on the comparison with regular training, that is, fast ball throwing, in subelite female players. Simultaneously, the current findings indicate that fast ball throwing contains a large resistance component as the ball is accelerated to large extent. It should be noted that this study cannot draw any conclusions with regard to long term effects or for elite players, which may be quite different. However, as we found no indication that pretest performance level played any role in the training effects, this study provides no reason to conclude that these findings do not apply for higher level athletes either.

Conclusion

The results of this study indicate that a short period of specific resistance training, mimicking the kinematics of the overam throw, does not surpass standard throwing training for improvement of throwing velocity in field handball for female subelite players.

References

1. Moritani T Time Course of Adaptations during Strength and Power Training. In: Komi PV, ed. *Strength and Power in Sport*. Oxford: Blackwell Science Ltd; 1992:266–278.
2. Kaneko M, Fichimoto T, Toji H, Suei K. Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. *Scand J Sports Sci.* 1983;2:50–55.
3. Van den Tillaar R. Effect of different training programs on the velocity of overarm throwing: A brief review. *J Strength Cond Res*. 2004;18:388–396.
4. Adams TB, Bangerter BL, Roundy ES. Effect of toe and wrist/finger flexor strength training on athletic performance. *J Appl Sport Sci Res.* 1998;2:3–34.
5. Barata J. Changes in ball velocity in the handball free throw, induced by two different speed-strength training programs. *Portugese J Human Perf.* 1992;8:45–55.
6. Bloomfield J, Blanksby BA, Ackland TR, Allison GT. The influence of strength training on overhead throwing velocity of elite water polo players. *Aust J Sci Med Sport*. 1990;22:63–67.
7. Brose DE, Hanson DL. Effects of overload training on velocity and accuracy of throwing. *Res Q*. 1967;38:528–533.
8. Gorostiaga EM, Izquierdo M, Itrralde P, Ruasta M, Ibanez J. Effect of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players. *Eur J Appl Physiol*. 1999;80:485–493.
9. Hoff J, Almåsbakk B. The effects of maximum strength training on throwing velocity and muscle strength in female team-handball players. *J Strength Cond Res*. 1995;9:255–258.
10. Lachowetz T, Evon J, Pastiglione J. The effect of an upper body strength program on intercollegiate baseball throwing velocity. *J Strength Cond Res*. 1998;12:116–119.

11. Logan GA, Mc Kinney WC, Rowe W, Jr, Lumpe J. Effect of resistance through a throwing range-of motion on the velocity of a baseball. *Percept Mot Skills*. 1966;23:55–58.
12. McEvoy KP, Newton RU. Baseball throwing speed and base running speed: The effects of ballistic resistance training. *J Strength Cond Res*. 1998;12:216–221.
13. Potteiger JA, Williford HN, Blessing DL, Smidt J. Effect of two training methods on improving baseball performance variables. *J Strength Cond Res*. 1992;6:2–6.
14. Wooden MJ, Greenfield B, Johanson M, Litzelman L, Mundrane M, Donatelli RA. Effects of strength training on throwing velocity and shoulder muscle performance in teenage baseball players. *J Orthop Sports Phys Ther*. 1992;15:223–228.
15. Caiozzo VJ, Perrine JJ, Edgerton VR. Training-induced alterations of the in vivo force-velocity relationship of human muscle. *J Appl Physiol*. 1981;51:750–754.
16. Neils CM, Udermann BE, Brice GA, Winchester JB, Mcguigan MR. Influence of contraction velocity in untrained individuals over the initial early phase of resistance training. *J Strength Cond Res*. 2005;19:883–887.
17. Toji H, Kaneko M. Effect of multiple-load training on the force-velocity relationship. *J Strength Cond Res*. 2004;18:792–795.
18. Toji H, Suei K, Kaneko M. Effects of combined training loads on relations among force, velocity, and power development. *Can J Appl Physiol*. 1997;22:328–336.
19. Andersen LL, Andersen JL, Magnusson SP, et al. Changes in the human muscle force-velocity relationship in response to resistance training and subsequent detraining. *J Appl Physiol*. 2005;99:87–94.
20. Roberton MA. Stability of stage categorizations across trails: implications for the ‘stage theory’ of overarm throw development. *J Hum Mov Stud*. 1977;1:49–59.
21. Van den Tillaar R, Ettema G. Influence of instruction on velocity and accuracy of overarm throwing. *Percept Mot Skills*. 2003;96:423–434.
22. Van den Tillaar R, Ettema G. Force-velocity relationship and coordination patterns in overarm throwing. *J Sports Sci Med*. 2004;3:211–219.
23. Kristensen GO, Ettema G, van den Tillaar R. Velocity specificity in sprint training. *J Strength Cond Res*. 2006;20:833–837.
24. Norenberg KM, Fitts RH. Contractile responses of the rat gastrocnemius and soleus muscles to isotonic resistance exercise. *J Appl Physiol*. 2004;97:2322–2332.