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STRENGTH, VELOCITY AND POWER USING LIGHT AND MEDIUM LOAD IN SPEED SKATERS

Raluca Doina Ștef (a)*, Emilia Florina Grosu (b)
*Corresponding author

(a) Babeș- Bolyai Univeristy, Faculty of Physical Education and Sports, Cluj–Napoca/ Romania, stefralucadoina@yahoo.ca
(b) Babeș- Bolyai Univeristy, Faculty of Physical Education and Sports, Cluj–Napoca/ Romania, emiliaflorina.grosu@gmail.com

Abstract

The aim of this study was to investigate the effect of a 8-week weight training intervention on 4 variables with different loads, light (30%) and medium (55%) from 1RM in junior speed skaters and control group. We hypothesized that a 8-week strength intervention in junior speed skaters would result in significant changes in height jump, peak power, peak velocity and peak force during a squat jump. Twenty participant divided into three groups: SJ (30%) (n = 5) 16.89 ± 1.8 years, SJ (55%) (n = 5), 16.93 ± 1.0 years speed skaters and control (n = 10), 17.05 ± 0.8 years as volunteers participated in this study. The testing protocol involved measuring a squat jump with two different loads: 30% and 55% of 1RM, assessing 4 components: height jump, peak force, peak velocity and peak power using Tendo Weightlifting Analyzer. The main finding of this study was that strength training improved all variables tested respectively: SJ (30) group a significant increase ($p < .05$) in (JH), (PV) and (PF) with both loads tested, and (PP) with 55% of 1RM and for SJ (55) group a significant increase was observed in (JH), (PP) and (PF) with both loads tested, meanwhile for (PV) with 30% and very significant ($p < .01$) for 55% of 1RM tested. These results suggest that using light and medium loads can be a useful method in improving (JH), (PV), (PF) and (PP), testing and monitoring the physical performance of speed skaters' off-season.

Keywords: Peak power, velocity, force, high jump, speed skating, squat jump.

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1. Introduction

Performance in speed skating is multifaceted, but the most important are physiological and biomechanical factors. In speed skating and also in many sports is required the ability to generate high amounts of force in relatively short periods of time (Kawamori & Haff, 2004; Newton & Kraemer, 1994) or the ability to express high power outputs (Haff, Whitley, & Potteiger, 2001; Haff et al., 2005). The overall relationship between sport-specific movements and the ability to generate high power outputs is well documented in the scientific literature (Baker & Newton, 2005; Bevan, et al., 2010).

Speed Skating is a sport characterized by force and speed, qualities needed for any of the distances skated. Power combines strength and quickness with speed and endurance, in order to have good speed you must have good power (Murray, 2005). When doing weight lifting athletes having the task to accelerate a given load and achieve high power outputs would seem to indicate what emphasis along the force-velocity spectrum, they need to emphasize to see further gains in power (Baker, Nance, & Moore, 2001).

1.1. The optimal load for highest power output

Heavy resistance training uses a relatively heavy load (>80% of 1RM) and is performed with a relatively slow velocity because of a large external resistance that must be overcome (Hakkinen & Komi, 1985; Harris, Stone, O'Bryant, Proulx, & Johnson, 2000; Hoffman, Ratamess, Kang, Rashti, & Faigenbaum, 2009). This method has been reported to increase maximum muscular strength and to result in enhanced muscular power or dynamic performance (Adams, O'Shea, O'Shea, & Climstein, 1992; Duchateau & Hainaut, 1984; Thompson et al., 2010) or to maintain training speed specificity and maximize mechanical power output.

Some authors have investigated the use of unloaded and loaded squat jumps in their assessment of lower body power while collecting force plate data (Baker et al., 2001; Sands et al., 2005; Stone et al., 2003; Wilson, Newton, Murphy, & Humphries, 1993). It has been suggested that when training to increase muscular power using loads which emphasizes the athlete's maximum power output may be advantageous for maximizing improvements in performance (Baker & Newton, 2005; Cronin, McNair, & Marshall, 2001; Kilduff et al., 2007; McBride, Triplett-McBride, Davie, & Newton, 2010). However, in his study Knudson (2009) is saying that, the peak power is not a fixed characteristic of a certain athlete, having fluctuations depending on different factors.

Programs dedicated to the development of power, however, may require athletes to train with loads substantially lower than the 1RM (Bevan et al., 2010; Fleck & Kraemer, 2004; Thomas et al., 2007; Wilson, Newton, Murphy, & Humphries, 1993; Zatsiorsky & Kraemer, 2006) as the value mentioned previously, respectively (> 80% from 1RM). One of the primary points of contention on the development of power through resistance exercise has been the type of loading to be used. Furthermore, because peak power occurs between 30 and 50% 1RM (Thomas et al., 2007), testing programs should evaluate low-speed strength with maximal loads, and the ability to perform high-velocity movements with submaximal loads.

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1.2. Validity of the instruments assessing the power output

Over the past 5 years, many studies have examined peak power output during training using either a Tendo FiTROdyne or a Tendo Weightlifting Analyzer (TENDO Sports Machines; Trencin, Slovak Republic) (Baker & Newton, 2005; Hoffman et al., 2009; Jones, Fry, Weiss, Kinzey, & Moore, 2008; Rhea, Peterson, Lunt, & Ayllo´n, 2008). In the studies that have utilized the Tendo Weightlifting Analyzer as a mean to measure power output it has been shown that results are reliable to asses power, force and velocity.

Thompson et al. (2010) in their study used the Tendo as an indicator for the peak power during a bench press. These measurements were then analysed through ratio and allometric scaling to determine its influence on normalizing peak power.

Overall, the Tendo has been used mainly for the comparison of different trials to each other, which has confirmed the reliability of the Tendo. By validating the Tendo, data collected are not only reliable but the measurements are correct in relationship to what is being measured. For example, Thompson et al. (2010) recently used peak power values from the Tendo Weightlifting Analyzer to normalize differences between division I collegiate football linemen and non–linemen using ratio and allometric scaling procedures.

Table 01. Participants characteristics

Variables	SJ (30%) (n = 5)		SJ (55%) (n = 5)		(C) (n = 10)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Age (years)	16.89 ± 1.8	-	16.93 ± 1.0	-	17.05 ± 0.8	-
Height (cm)	176.5 ± 3.0	-	178.3 ± 2.2	-	179.5 ± 2.0	-
Weight (kg)	80.3 ± 3.5	80.6 ± 3.6	80.5 ± 2.8	80.6 ± 2.9	78.1 ± 3.2	78.5 ± 3.3

There were no significant differences between or within the groups for any of the participant characteristics variables pre or post intervention (Table 1).

2. Problem Statement

One of the important aspects to follow in the development of power is the type of load used and the speed at which the movement is executed. Indications are directed towards encouraging athletes to accelerate in the concentric phase of the movement despite the difficulty imposed by the load and try obtaining the highest possible jump.

So far there have been attempts to gain insight into the squat jumps executed by skaters (Baker et al., 2001) but:

- no study is known to compare the values of force, power and velocity achieved during a light-load (30% of 1RM) and medium-load (55% of 1RM) during a squat jump in junior speed skaters,
- to our knowledge, the effects of a strength training intervention longer than 8 weeks, on peak power, peak force, peak velocity and jump height in speed skaters is unknown.

Previous research has reported that based on the load, velocity, and mechanical specificity of muscular-power development, it appears plausible to train continually at the load that maximizes mechanical power output in order to improve maximal muscular power. Investigators strongly believe in the importance of these exercises to improve maximum strength, at which would contribute to the muscular-power development (Izquierdo et al., 2001). This may indicate why previous investigations have found both heavy and light resistance training to be effective in improving athletic performance (Haff et al., 2005).

However, Bevan et al. (2010) recommended that athletes train with loads that are a little lighter than the optimal load that maximizes power output, and that the optimal load should be used only in the last few weeks of a training cycle. Although the use of squat jumps, with and without loads, as a strength and power assessment is not novel (Baker et al., 2001; McBride et al., 2010).

It may be the fact of moving quickly and not the actual movement speed that determines the velocity – specific response. Some authors suggest that when training for dynamic athletic performance the movement speed is not important as long as the intent of muscle action is explosive (Cormie, McGuigan, & Newton, 2011). Our findings are contradictory because both groups in this study were given specific instructions to initiate the movement as quickly as possible. Each subject performed the movement with no voluntary deceleration in the concentric phase. Therefore, it appears that the actual velocity of training, as indicated by the SJ (55), is a vital component of producing high velocity, force and power capabilities.

3. Research Questions

Testing speed skaters in sport specific conditions is still difficult because of the temperature, humidity etc. variables that may be tricky in obtaining valid results. Because of this testing impediments, evaluating athletes in laboratories is a necessity in particular for countries with less sports- specific training conditions. Also, because strength training is a big part of training program during off – ice season this kind of testing suits to the needs of evaluating improvements in physical performance in a similar sport specific movement.

Based on this information the research question is:

Does a 8-week weight training intervention has an influence on developing peak power, peak velocity, peak force and increasing jump height when using light and medium load in junior speed skaters?

4. Purpose of the Study

The purpose of this study was to investigate the effect of a 8-week weight training intervention on 4 variables with different loads, light (30%) and medium (55%) from 1RM in junior speed skaters and control group, variables measured pre and post intervention. We hypothesized that a 8-week strength intervention in speed skaters would result in significant changes in peak power, peak velocity, peak force and height jump during a squat jump.

5. Research Methods

In this study participated 20 athletes aged between 15-18 years with 2-3 years of resistance training experience. The subjects in the experiment group SJ (30%) (n = 5) 16.89 ± 1.8 years and SJ (55%) (n = 5), 16.93 ± 1.0 years are legitimated to a sports club following two types of training protocols respectively SJ (30%) and JS (55%) of the previous determination of 1RM (repetition maximum) and those in the control group (C) (n = 10), 17.05 ± 0.8 years participating as volunteers.

Participants were chosen that were not taking, and had not previously taken, anabolic steroids, growth hormone, or related performance-enhancement drugs of any kind. Prior approval by the national coach was obtained for this study. All subjects were informed of any risks associated with participation in the study and signed an informed consent document before any of the testing.

5.1. 1RM Testing

Before each test period, the subjects had the opportunity to familiarize themselves with the procedures applied (with 48h before). The day of familiarization assumed the same steps in the test protocol. Before the start of the test was performed a 10-minute warm-up on the ergometric bike (XTPRO Bike 600, Tehnogym Usa Corp., U.S. A), followed by 5 minutes stretching exercises. After approx. 2 minutes the subjects started 1RM test protocol (Murray, 2005). This protocol consists of a warm-up with an estimated load of 10 reps x 50%-, 5 reps x 70%, 3 reps x 80% and 1 rep x 90% of 1RM (3 minutes rest between sets). After warm-up the load was progressively increased, each subject having 3-4 attempts (maximum efforts) to determine 1RM.

After the determination of 1RM, subjects performed a squat jump using the Olympic bar (20kg) with the additional load according to the test protocol, 30% and 55% of 1RM. To measure the desired variables, the Tendo Weightlifting Analyzer (TENDO Sports Machines, Trecin, Slovak Republic) was used and the mat (Tendo WL package) to measure the jump height. The data was collected using the software Tendo Softaware Computer V-5 (Version 6.0.1, Slovak Republic).

Before testing, a series of 6 repetitions were performed only with the bar. The load used was increased exponentially starting from 30% to 55% of 1RM. Subjects were told that after reaching this point to accelerate the concentric phase of movement as quickly as possible, followed by a vertical jump with maximum height. 3 attempts were allowed for each load.

5.2. Squat jump testing

The study has a longitudinal design, in which three groups participated, the two experimental groups and one control group (C) (Table 1). Two treatment groups followed two different training protocols, respectively SJ (30%) (n = 5): training with 30% of 1RM) and SJ (55%) (n = 5:) training with 55% of 1RM) after which they performed a squat jump test with both loads 30% and 55% of 1RM. The third group served as controls (C). The test periods were grouped in two weeks, pre and post-test and the intervention period of 8 weeks of strength training (2 times a week with a duration of approx. 60min). All training was assisted by the researcher.

Testing involved a light-weight squat jump with 30% of 1RM and medium -weight squat jump with 55% of 1RM. Before each test the subjects performed a warm-up on the ergometric bike for 10 min

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with a standard resistance imposed - 105W (XTPRO Bike 600, Tehnogym Usa Corp., U.S.A), followed by 5 minutes stretching exercises. Approximately 2 minutes later testing began. All trainings were performed using an Olympic bar (Olympic Sportmann Romania, 20kg) to which the load was added according to 1RM determined on each subject. To evaluate the peak power (PP), peak force (PF), peak velocity (PV) and jump height (JH) for each repetition we used Tendo Weightlifting Analyzer (TENDO Sports Machines, Trecin, Slovak Republic) and in addition was used the mat to measure the height of the jump. Data was collected using the software (Tendo Softaware Computer V-5. Version 6.0.1, Slovak Republic).

The training program included two strength trainings per week for the experiment group. The subjects in the experiment group performed a warm-up of 10 minutes on the ergometric bike with a standard resistance - 105W (XTPRO Bike 600, Tehnogym Usa Corp., U.S. A), followed by 5 minutes stretching exercises. Approximately 2 minutes later testing began. Both experimental groups performed two series of 6 repetitions with 20kg, after which they followed two different types of training protocols according to the sampling of those with light load 30% of 1RM, a series of 5 sets and with medium load 55% of 1RM, a series of 4 sets.

The number of repetitions performed in each set was determined on the basis of the decrease of the peak power output of 15%. This level was chosen as a reference point corresponding to a significant decrease in the maximum speed obtained between the required loads (30%, 55%) each repetition was considered correct when the angle determined by the knee flexion was 90 degrees, representative for speed skating, ideal for producing maximum force and power in a side push, followed by an explosive jump to achieve maximum jump height. The task of each subject was to perform each repetition at maximum speed, exerting a maximum force. The control group did not perform additional explosive exercises and were told to follow their daily training regimen between the test periods.

6. Findings

The main finding of this study was that strength training significantly improved force, velocity and power which determine the value of the height jump, specifically for treatment groups. The correlation between these variables is very significant which means that power, force and velocity have a direct impact in achieving a maximal high jump, regardless the load used. All these variables are interconnected and if one or two represent a weak point then it reflects on the final result, showed in the height of the jump obtained. Interestingly, the improvements in (PP) for SJ (30) were greater using 55% of 1RM and for SJ (55) group were greater for (PV) using 30% and very significant using 55% of 1RM.

There was no significant difference between the number of workouts or the total number of sets including the warm-up sets or repetitions performed between the SJ (30%) and SJ (55%) groups. No significant difference between total work and changes in performance variables were found. For the squat, testing 1RM, there was a significant increase in the final load rise for both SJ (30%) and SJ (55%) groups from pre to post testing periods (Figure 01).

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6.1. Squat jump testing comparisons between variables

After a 8-week strength training period, notable changes were observed by the testing protocol. We found a significant increase in jump height (JH) for (C) group with 30% of 1RM and for the SJ (30) and SJ (55) for both loads tested. Concerning the peak power (PP), results showed a significant increase for (C) group measured with 30% of 1RM for SJ (30) with 55% and for the SJ (55) for all loads tested. For the peak velocity (PV), results showed a significant increase for (C) group with 55% of 1RM, for SJ (30) with both loads used and for the SJ (55) with 30% of 1RM and a very significant one with 55%. Results obtained for the peak force (PF), showed for (C) group a significant increase with 30% for SJ (30) and SJ (55) with both loads tested.

6.2. Squat jump testing correlations between variables

A Colton correlation was computed to assess the relationship between the variables measured peak power, peak force, peak velocity and jump height for control and intervention groups. The analysis revealed that there is a positive and strong correlation between all variables. These results support the hypothesis that a 8-week strength intervention in speed skaters would result in significant changes in peak power, peak velocity, peak force and height jump during a squat jump. Our findings for the three groups are described below:

The correlation between variables measured in (C) group showed Post intervention for the 30% of 1RM tested, a very good correlation between all variables HJ- PP ($r/\rho = 0.84$, $p <0.001$), HJ- PV ($r/\rho = 0.87$, $p < 0.001$) and HJ- PF ($r/\rho = 0.81$, $p < 0.001$) and PV- PP- ($r/\rho = 0.89$, $p < 0.001$) ; PV-PF ($r/\rho = 0.82$, p 0.001) same values were found for 55% of 1RM post intervention.

The correlation between variables measured in SJ (30) group showed Post intervention with 30% of 1RM tested, a good and positive correlation between HJ-PP (($r/\rho = 0.70$, p 0.001), HJ-PF (($r/\rho = 0.63$, p 0.001); PP-PV ($r/\rho = 0.70$, p 0.001), and for the 55% of 1RM a very good correlation and positive between HJ-PP ($r/\rho = 0.98$, p 0.001), HJ-PV ($r/\rho = 0.98$, p 0.001), PP-PV ($r/\rho = 0.98$, p 0.001).

The correlation between variable measured in SJ (55) group Post intervention with 30% of 1RM, was very good and positive between HJ-PP ($r/\rho = 0.96$, p 0.001), HJ –PV ($r/\rho = 0.98$, p 0.001), HJ-PF ($r/\rho = 0.80$, p 0.001); PP-PV ($r/\rho = 0.98$, p 0.001), PP-PF ($r/\rho = 0.78$, p 0.001), PV-PF ($r/\rho = 0.81$, p 0.001). And with 55% of 1RM, very good and positive between HJ-PP ($r/\rho =$,0.93, p 0.001), HJ-PV ($r/\rho = 0.94$, p 0.001); HJ-PF ($r/\rho = 0.82$, p 0.001), PP-PV ($r/\rho = 0.85$, p 0.001), PP-PF ($r/\rho = 0.93$, p 0.001), PV-PF ($r/\rho = 0.75$, p 0.001).

- Statistical analysis for jump height obtained for the two loads confirmed between Pre and Post training intervention statistical significant differences ($p < 0.001$) between (C), SJ (30) and SJ (55) groups tested with 30% and 55% of 1RM.
- Statistical analysis for peak power (PP), showed between Pre and Post training intervention: significant differences for SJ (30) with 55%, for (C) and SJ (55) with both loads.
- For peak velocity (PV), were observed between Pre and Post training intervention: significant differences ($p < 0.001$) for (C) with 55% of 1RM, for SJ (30) with all loads and for SJ (55) only with 30% of 1RM.

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- We found very significant differences (p < 0,001) for SJ (55) with 55% of 1RM. For peak force (PF) were observed between Pre and Post training intervention: significant differences (p < 0.01) for (C) with 30% of 1RM, for SJ (30) SJ (55) with both loads.

Table 2 presents the results obtained for each variable in pre and post testing periods. No significant differences were observed for any strength measures between the intervention and control groups at baseline. The change in absolute maximal strength in the intervention group SJ (30%) (Pre 90.0 ± 9.8 to Post 102.5 ± 10.2), was significant different from Pre to Post- test within the group. However, the change in relative maximum strength (1RM back squat) in the intervention groups SJ (30%) and SJ (55%) (Pre 96.5 ± 10.1 to Post 112.5 ± 10.3) was significantly increased from Pre to Post test (p < 0.05).

Table 02. Training protocol and 1RM

Variables	**SJ (30%) (n = 5)**		**SJ (55%) (n = 5)**		**(C) (n = 10**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Workouts (no.)	-	13.5 ± 0.4	-	13.2 ± 0.2	-	-
Total sets (no.)	-	82.1 ± 2.9	-	80.8 ± 2.5	-	-
Total rep. (no.)	-	512.5 ± 24.0	-	442.7 ± 22.4	-	-
1RM (kg)	90.0 ± 9.8	102.5 ± 10.2*	96.5 ± 10.1	112.5 ± 10.3*	92.0 ± 7.9	100.2 ± 7.3

*Note: A significant difference from Pre to Post for that group

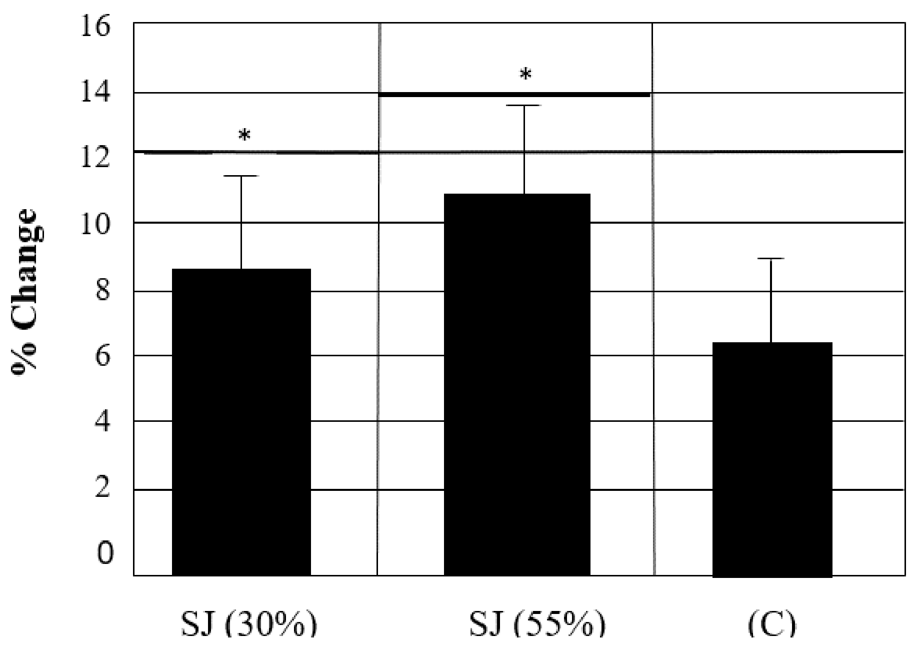

Figure 01. Percentage change in maximum squat strength (1RM) from Pre to Post training intervention. * = significant difference from before Pre to Post for that group (p ≤ 0.05)

7. Conclusion

Results show some changes in variables tested for the controlled group too. However, in this group subjects had approximate three years of strength experience and were implicated in different types of sports activities that may have influenced the values of variables measured, independent of the effects of

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the testing protocol itself. Increases in height jump (HJ), peak power (PP), peak force (PF) with 30% and peak velocity (PV) with 55%, in the (C) group, supports this concept in that the improvements in strength and power were not specific to the treatment but a result of outside activity.

These results suggest that using light and medium loads can be a useful method in testing and monitoring the physical performance of speed skaters. This strongly supports the application of strength training within the speed skating community, demonstrating that to optimize performance in short and middle distances, strength training should be a vital component in the physical preparation of speed skaters in particular during off – season.

The patterns of velocity and force capabilities were more pronounced between these groups at testing loads closer to the load at which each group trained. However, the pattern of velocity or force and power capabilities incomparable to each group was observed over the both testing loads. A previous study on this topic (Jennings, Viljoen, Durandt, & Lambert, 2005) a cross- sectional analysis of various athletes, reported that power lifters had the ability to produce large forces but they had a relatively low ability to produce high velocities.

In addition, this load used during training appears to have a differential effect on force, velocity, and power variables relating to physical performance. This means that subjects regardless the group of which they were part of, following two different types of training protocol, were ask to move the bar as quickly as possible for each repetition. For the SJ (55) group, the load of the bar was determined at what velocity the training would occur.

The results obtained for this group showed a faster velocity than the SJ (30) group which had a light load on the bar. The group in question, SJ (55) had an overall trend of improvement velocity capabilities regardless the load but still with a significant increase with 55% of 1RM in jump squat test.

Significant increases in peak power was found for the SJ (30) group at both of the loads tested but still with a significant increase with 55% of 1RM jump squat tested. Both groups, SJ (30) and SJ (55), had significant improvements in jump height (HJ), peak force (PF) with differences regarding the peak velocity (PV) mentioned for the SJ (55) and peak power (PP) for the SJ (30).

Related to the high correlations observed in our investigations between all variables measured, we can conclude that there is a strong, positive and linear relation between force, velocity and power variables that strongly influence the height of the jump obtained. This type of training protocol used in our study is important for developing muscular power as a result of high correlations at light (30% of 1RM) as well as at medium load (55% of 1RM). Stone et al. (2003) suggested that maximum strength plays a major role in power output and that power may be increased with the improvement of maximum strength.

7.1. Training design to enhance power output

Taking into account the above mentioned we suggest the use of different types of exercises, like Olympic-style lifts and their derivatives (e.g., power clean, snatch) that are also considered the best training exercises to maximize muscular power and dynamic athletic performance because they are multi joint exercises, they do not have the problem of deceleration phase, and they produce some of the highest average human power outputs of all the resistance-training exercises (Haff et al., 2005; Stone et al., 2003). Besides that, results are indicating that both heavy resistance and explosive-type resistance training should be included in resistance-training programs to develop muscular power and athletic performance.

Maximal mechanical power has been thought to occur at a resistance of 30% of maximum isometric strength (Faulkner, Claflin, & Mccully, 1986) or 30– 45% of 1 repetition maximum (1RM) (Harris et al., 2000; Newton, Cormie, & Cardinale, 2011).This findings from the current investigation are consistent with these previous findings. Training with an optimal load and thus velocity results in velocity-specific increases in muscle activation. Thus, it appears that the velocity of the movement, as controlled by the load, plays a key role in improving high-velocity performance capabilities and power output.

As reported, combined training method has also been proven useful to develop muscular power and a wide variety of athletic performances (Adams et al., 1992; Haff et al., 2001; Rhea et al., 2008). This combination could be heavy resistance/plyometric training (Adams et al., 1992) heavy resistance/explosive-type resistance training (Harris et al., 2000; McBride et al., 2010), heavy resistance training/sports-specific task or explosive-type resistance training/sports-specific task (Cormie et al., 2011).

7.2. Training design to enhance velocity

In conjunction with sport-specific testing and 1RM testing during off – ice season assessing the force-velocity qualities of the leg extensors against a range of external loads can provide the strength and conditioning coach with insight into the training needs of an individual athlete. If a speed skater's results demonstrate that his acceleration and velocity is poor as external load is added, then the coach can use this information by designing the training accordingly (i.e., emphasis on heavy load strength and high load power training). If another speed skater demonstrates that he decreases very little in his acceleration and velocity qualities as external load is added, yet low load power is considered an important attribute for this athlete, the coach can design training accordingly (i.e., emphasis on unloaded/low load jumps, plyometrics, etc.). However, this type of training model used in this investigation is more applicable to sports in which velocity changes over the course of a specific movement.

Results show that this type of training induces improvements in all variables measured which contributes to actual speed skating performance on and off ice. Additionally, these findings could help strength and conditioning coaches adjusting the strength program for ones weaknesses regards one of the aspects mentioned above among young skaters. Therefore, this study makes it possible to evaluate multiple variables during a squat jump with different loads and measuring if whether or not skaters are capable of maintaining physical capabilities such as force, speed and power during a period of time.

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Corresponding Author: Raluca Doina Ştef
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