Original Article

Speed and power predictors of change of direction ability in elite snow athletes

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ABSTRACT

Schultz, F.A., Cavazzoni, P., Carnevale, R.V., Abad, C.C.C., Kobal, R., Pereira, L.A., & Loturco, I (2015). Speed and power predictors of change of direction ability in elite snow athletes. *J. Hum. Sport Exerc., 10*(4), pp.847-856. Change of direction ability (COD speed) is an important physical component of snow sports. The aim of this study was to investigate the relationships between regular speed and vertical jumping ability, and COD speed in elite snow athletes. Moreover, the correlations between relative mean propulsive power (assessed in the jump squat exercise) and COD speed were quantified. Sixteen elite snow sport athletes executed squat jumps, countermovement jumps, jump squats, and 25 m sprint tests, in addition to a Zig-zag change of direction speed test. The outcomes revealed that vertical jumping height and mean propulsive power are strongly correlated ($r \approx 0.90$) with COD speed. Furthermore, snow athletes capable of sprinting faster in a linear course of 25 m performed better in COD speed tests ($r = 0.91$). Our results support the use of loaded and unloaded vertical jumping and regular speed tests to evaluate/monitor predictors of COD speed in elite snow athletes. Finally, these relationships suggest that plyometrics and regular speed training should be considered by coaches as effective strategies to enhance COD ability in this specific group of subjects. **Key words**: OLYMPIC ATHLETES; WINTER SPORTS; COD SPEED; ELITE ATHLETES; JUMP SQUAT.

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INTRODUCTION

Speed and muscle power play an important role in sports performance. Therefore, several training methods are proposed to improve these physical capabilities, such as heavy resistance training and optimum power-load regimens (Harris et al., 2008; Loturco et al., 2013a). The choice of the best training method is based mainly on three concepts: the sport specificity, the training results, and the physiological adaptations.

Physical tests are often used by researchers and coaches in their efforts to verify and to quantify the physiological and/or neuromuscular adaptations following a respective training period (i.e., improvements in strength, power and speed) (Loturco et al., 2013b; Newton et al., 1999). In this regard, standardized field-tests (i.e., vertical jumping tests, sprint tests, etc.) are known as simple, inexpensive, reliable and valid sport-performance measurement tools (Delextrat & Cohen, 2008; Drinkwater et al., 2008; McBride et al., 2009; Raschner et al., 2013). For strength and conditioning coaches, the criterion for selecting the most appropriate test for evaluating an athlete's physical ability is its relationship with the specific sports performance.

Cross-sectional correlational analysis studies are widely used by researchers to investigate the relationship between selected strength/power tests and specific athletes' performance (Delextrat & Cohen, 2008; Hansen et al., 2011; López-Segovia et al., 2011; Turner et al., 2012; Ziv & Lidor, 2010). For instance, in elite karate athletes, power output and jump height measured during loaded and unloaded vertical jumping tests have already been shown to be important predictors of punching acceleration (Loturco et al., 2014). Also, several studies have reported significant correlations between vertical/horizontal jump tests and sprinting speed over different distances (Hansen et al., 2011; Harris et al., 2008; López-Segovia et al., 2011; Sleivert & Taingahue, 2004). Despite the relevance of correlational analysis for elite athletes' training and testing, the scarcity of research about this theme in snow sports is surprising. Thus, it is difficult for coaches and technical staff involved in snow sports to determine the best testing routines for assessing elite snow athletes.

It has already been reported that the capacity to change direction rapidly (COD speed) (i.e., Swiss cross test) is an important ability in snow sports (Heikkinnen, 2003; Gorski et al., 2014). A high level of COD speed is essential for elite athletes in a wide range of snow sport modalities, such as cross-country skiing (during downhill turning movements) and slalom competitions (during successive "zig-zag" movements) (Heikkinnen, 2003; Sandbakk et al., 2014a; Turnbull et al., 2009). Moreover, better outcomes in COD tests were correlated with superior performance levels in elite slalom events (Heikkinnen, 2003). Finally, the combination of a good ski technique together with higher levels of leg muscle can be important for increasing and/or reducing the athletes' velocities during turning movements in specific downhill skiing (Sandbakk et al., 2014a; Sandbakk et al., 2014b; Perrey et al., 2000). In addition, it appears that the stretching-shortening cycle (SSC) has a crucial participation in turning movements, for both cross-country skiing and slalom events (Perrey et al., 2000; Heikkinnen, 2003). This relationship emphasizes the role of plyometrics in snow sports performance.

The development of muscle strength and power in endurance skiers is related to improvements in cross-country ski performance, which is explained by improved work economy (Hoff et al., 2002; Hoof et al., 1999; Losnegard et al., 2011). Furthermore, Platzer et al. (2009) reported that a snow athletes' performance measured by the International Ski Federation score (i.e., FIS points) is correlated with the countermovement jump height and lower limb muscle power (assessed by isokinetic testing). Similarly, Gorski et al. (2014) observed significant differences in standing horizontal jumps between athletes selected or non-selected for the Swiss alpine national team (longer vs. shorter horizontal jump-distances for selected or non-selected, respectively). Finally, the specific transference of the lower limb muscle strength/power to elite snow athletes' performance has been extensively evidenced in the specialized literature (Platzer et al., 2009; Patterson et al., 2009; Stoggl et al., 2011; Sandbakk et al., 2014a).

In spite of the importance of these physical abilities (COD, muscle power and speed) for snow sports performance, no study has investigated the relationship among these capacities in snow elite athletes. It is especially important in order to develop a precise testing routine capable of assessing and/or predicting elite snow athletes' performance. Moreover, the possibility of evaluating this particular group of athletes in non-snow environments could be very interesting, particularly for athletes living in tropical countries and/or for weather periods without snow cover. Therefore, the aim of this study was to test the correlations between lower limb muscle power (assessed in loaded and unloaded vertical jumps), regular speed and COD speed ability in Brazilian elite snow sports athletes. Based on the published data that have already shown important associations between COD speed and power and speed performance in elite athletes who compete in a wide range of sports practiced in non-snow environments (Barnes et al., 2007; Nimphius et al., 2010), we hypothesized that the snow athletes with higher levels of muscle power would perform better in COD tests.

MATERIAL AND METHODS

Participants

Sixteen elite snow sport athletes, top-ranked in the Brazilian Snow Sports Federation (9 men and 7 women; age: 25 ± 7 years; height: 171 ± 10 cm and body mass: 63.7± 10.5 kg) volunteered to participate in the study. The sample comprised athletes who took part in the Winter Olympic Games, World Championships, World Cups and South American Cups, all of them currently ranked in the Top 3 of the national rank of their respective disciplines, attesting to their high level of competitiveness. Athletes were informed of the experimental risks and benefits of the study, and signed an informed consent form prior to the investigation. An Institutional Review Board for use of human subjects approved the study.

Experimental Design

Prior to the assessments, the snow sports athletes were familiarized with the experimental procedures during three non-consecutive sessions, which took place over two days, separated by at least 24 h. The order of the assessments was as follows: day 1: unloaded vertical jump tests (squat jump and countermovement jump) and loaded vertical jump tests (jump squat); day 2: sprint and COD speed tests. Before the two testing sections, the participants performed standardized warm-up protocols including general (i.e., running at a moderate pace for 5 min followed by active lower limb stretching for 3 min) and specific jump and sprint exercises, at submaximal intensities. The warm-up was followed by a 3 min interval, after which the players were required to execute the actual tests.

Vertical jumping ability

Vertical jumping ability was assessed using squat and countermovement jumps. In the squat jump (SJ), a static position with a 90° knee flexion angle was maintained for 2 s before a jump attempt without any preparatory movement. In the countermovement jump (CMJ), the athletes were instructed to perform a downward movement followed by a complete extension of the lower limbs, freely determining the amplitude of the countermovement to avoid any changes in jumping coordination pattern. All the jumps were executed with the hands on the hips. The jumps were performed on a contact platform (Smart Jump; Fusion Sport, Coopers Plains, Australia) with the obtained flight time (t) being used to estimate the height of the rise of the body's center of gravity (h) during the vertical jump (i.e., h = gt2/8, where g = 9.81 m·s-2). Five attempts at each jump were performed with a 15 s interval between each attempt. A given jump would only be considered valid for analysis if the take-off and landing positions were visually similar. The best attempt was used for data analysis purposes.

Mean propulsive power and bar-velocity in jump squat exercise

Mean propulsive power and bar-velocity were assessed in the jump squat exercise (MPP and VEL JS, respectively), performed on a Smith machine (Technogym Equipment, Italy). The subjects executed a knee flexion until the thigh was parallel to the ground and, following a command, jumped as fast as possible, without their shoulder losing contact with the bar. The athletes were instructed to execute 3 repetitions at maximal velocity for each load, starting at 40% of their BM. A further load of 10% of BM was gradually added in each set until a decrease in mean propulsive power was observed. A 5 min interval was allowed between sets. To determine mean propulsive power, a linear transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith machine bar. The bar position data were sampled at 1,000 Hz using a computer. To calculate the velocity and acceleration of the bar the finite differentiation technique was used. Mean propulsive power rather than peak power was used in the jump squat since Sanchez-Medina et al. (2010) demonstrated that mean mechanical values during the propulsive phase better reflect the differences in the neuromuscular potential between 2 given individuals. This method avoids underestimation of true strength potential since the higher the mean velocity (and lower the relative load), the greater the relative contribution of the braking phase to the entire concentric time. For data analysis purposes, we considered the maximum mean propulsive power value and the highest velocity value obtained. In order to avoid misinterpretation of the power outputs, we normalized these values by dividing the absolute power value by the body mass (i.e., relative power = W.kg-1, MPP REL).

Sprinting speed

Two pairs of photocells (Smart Speed, Fusion Equipment, AUS) were positioned at distances of 0 and 25 m along the course, prior to the execution of the speed tests. The sprint tests were performed on an indoor running track in order to avoid weather influences. The athletes started from a standing position, 0.3 m behind the start line and sprinted twice with a 5 min rest interval between the two attempts, the fastest time realized being retained for the analyses.

Zig-zag change of direction speed (COD speed test)

The COD speed test was chosen due to its similarity to snow sports turning movements, during which the athletes have to decelerate and accelerate as fast as possible, without losing their body stability (Figure 1). The course consisted of four 5 m sections marked with cones, set at 100° angles. The snow sports athletes performed two maximal attempts, with a 5 min rest interval between attempts. Starting from a standing position with the front foot placed 0.3 m behind the first pair of photocells (i.e., starting line), the athletes ran and changed direction as quickly as possible, until crossing the second pair of photocells, placed 20 m from the starting line (Little et al., 2006). The best time from the two attempts was retained for further analysis.

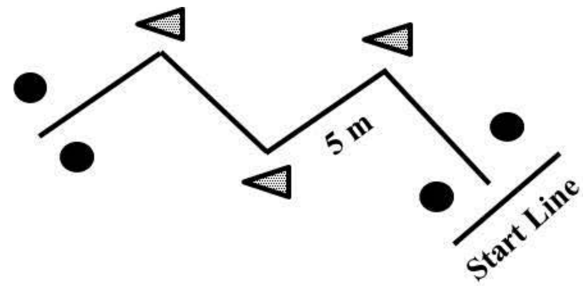

Figure 1. Diagram of the course used in the COD speed test. Each straight sprint is 5 m and each turn at a cone is 100o. The circles represent the position of the photocells.

Statistical Analyses

Data normality was checked through the Shapiro–Wilk test, and was expressed as means and standard deviation (SD). The relationships between jump outcomes (in loaded and unloaded conditions) and sprinting tests (linear and COD speed) were determined via Pearson correlation coefficient, with 95% confidence interval (95% CI) being tested for all tested variables. As 95% CI correlation coefficients did not differ between men and women, the genders were grouped and only the significant correlation coefficients for all the athletes were reported. Simple linear regression models were calculated using the SJ and CMJ as independent variables, in order to help elite snow coaches to estimate the extent of change in COD speed to a given change in jump performance. Total variances are reported in figure 2 (panel A and B) together with the coefficient of determination (R2). The significance level was set as *P* <0.05.

RESULTS

Table 1 shows the descriptive data (Mean ± SD and confidence interval, CI 95%) of performances in loaded (JS) and unloaded (SJ and CMJ) jump tests, sprinting speed and COD speed. The correlations between the results in loaded (JS) and unloaded (SJ and CMJ) vertical jump tests, sprinting speed and COD speed are presented in table 2. Strong correlations were found between all variables analyzed. Figure 2 (A and B) shows a linear regression of unloaded vertical jump tests (SJ and CMJ) and COD speed.

Table 1. Results of vertical jump tests (loaded and unloaded conditions), sprinting speed and COD speed in elite snow sports athletes.

	Mean ± SD	CI (95%)	
		Lower	Upper
SJ (cm)	34.68 ± 8.3	30.08	39.28
CMJ (cm)	35.7 ± 8.93	30.75	40.65
VEL 25 m ($m.s^{-1}$)	6.37 ± 0.57	6.05	6.68
MPP REL($W.kg^{-1}$)	5.59 ± 1.81	4.59	6.6
VEL JS ($m.s^{-1}$)	1.13 ± 0.18	1.03	1.23
COD Speed ($m.s^{-1}$)	3.53 ± 0.18	3.42	3.63

SJ = squat jump; CMJ = countermovement jump; VEL 25 m = velocity in 25 m sprint; MPP REL = mean propulsive power relative to body weight; VEL JS = velocity of bar in the jump squat exercise; COD Speed = speed in the change of direction test

Table 2. Correlations between the results in loaded (JS) and unloaded (SJ and CMJ) vertical jump tests, sprinting speed and COD speed in elite snow sports athletes.

	SJ	CMJ	VEM 25 m	MPP REL	VEL JS	COD Speed
SJ		0.98**	0.94**	0.84**	0.91**	0.89**
CMJ	0.98**		0.94**	0.86**	0.91**	0.91**
VEL 25 m	0.94**	0.94**		0.85**	0.90**	0.91**
MPP REL	0.84**	0.86**	0.85**		0.95**	0.88**
VEL JS	0.91**	0.91**	0.90**	0.95**		0.87**
COD Speed	0.89**	0.91**	0.91**	0.88**	0.87**	

SJ = squat jump; CMJ = countermovement jump; VEL 25 m = velocity in 25 m sprint; MPP REL = mean propulsive power relative to body weight; VEL JS = velocity of bar in the jump squat exercise; COD Speed = speed in the change of direction test. ***P* < 0.01

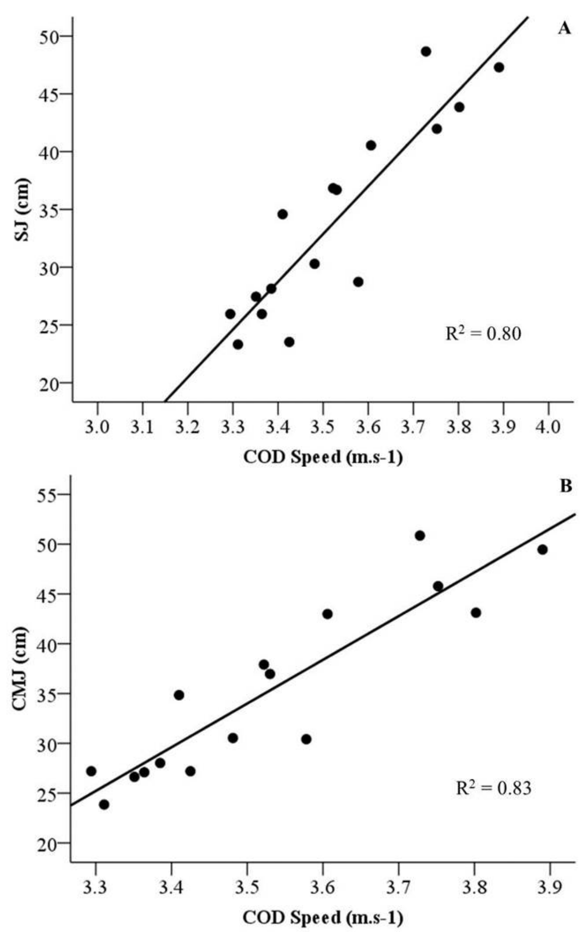

Figure 2. Linear regression of unloaded vertical jump tests (SJ and CMJ) and COD speed in elite snow sports athletes.

DISCUSSION

The main purpose of this study was to test the association between loaded (JS) and unloaded (SJ and CMJ) vertical jumps, regular speed and COD speed in Brazilian elite snow sports athletes.The main findings of the present study were twofold: 1) there was a significant correlation (r = 0.91) between 25 m regular sprinting speed and COD speed; 2) strong correlations were observed between unloaded (SJ and CMJ) and loaded (MPP REL) vertical jump tests and COD speed (r = 0.89, r = 0.91, and r = 0.88 for SJ, CMJ, and MPP REL, respectively).

It has already been suggested that COD speed seems to be an important physical ability for snow sports success (Heikkinnen, 2003; Gorski et al., 2014; Sandbakk et al., 2014a). In this study, snow sports athletes capable of sprinting faster over short distances in a regular trajectory performed better in COD speed tests. Several authors have described similar relationships between regular and COD speed tests in various sports modalities (Alemdaroglu, 2012; Chaouachi et al., 2012; Lockie et al., 2013). Although changing of direction demands specific technical abilities to accelerate, decelerate and turn more quickly, it appears that the neuromechanical components of sprinting can influence specific COD ability. It emphasizes the necessity to train and to improve linear speed in this group of snow athletes, through the prescription of specific/regular speed training.

Also for CMJ and SJ heights, the data presented herein showed strong correlations between vertical jump height and COD speed (r = 0.89, r = 0.91, respectively). These relationships have already been reported in previous investigations composed of elite athletes from other modalities (Alemdaroglu, 2012; Chaouachi et al., 2012; Lockie et al., 2013). To our knowledge, this is the first study to show these associations in an elite group of snow athletes. It appears that the difference in the competitive and/or training surfaces (i.e., snow surfaces) do not affect the level of the associations between the related variables (vertical jump height and COD speed). Additionally, as already mentioned, it has been reported (Perrey et al., 2000) that SSC plays an important role in turning movements involved in downhill skiing actions. Although correlations do not imply a direct relationship between cause and effect, our results highlight the importance of plyometrics within a specific snow athletes training routine.

We observed a strong correlation (r = 0.88) between relative MPP REL and COD speed. Several studies have reported that lower limb power ability is significantly associated with COD speed (Young et al., 1996; Young et al., 2002). Furthermore, it was reported that a training period consisting of 8 weeks of JS induced significant improvements in jumping power (10%) and a smaller but significant improvement in COD speed (1.7%, assessed by an agility T-test) (McBride et al., 2002). In our results, the nearly perfect correlations between the relative mean propulsive power and COD speed could have been influenced by the test-type used, since we selected the zig-zag set-up (instead of the T-test) to assess our snow athletes. In this type of COD test, the deceleration and acceleration abilities over very-short distances play an important role in the athletes' performances. Actually, ballistic exercises (e.g., JS exercises) have a great similarity with short-sprint-movement patterns, since they allow projection of the athletes or a lift, and have acceleration and deceleration phases (Newton & Kraemer, 1994; Saez De Villarreal et al., 2013).

Finally, it seems that the physical abilities that determine COD speed are very similar to some abilities involved in snow sports situations, since the snow athletes have to use their body stability, motor control and specific coordination for turning faster, without prejudicing their technical patterns. In this study, the strong correlations between loaded/unloaded vertical jump tests and COD speed are important indicators that lower limb muscle power can explain, to some extent, the athletes' capacity to change direction efficiently. Moreover, the relationship between linear speed and COD speed reported herein emphasizes the necessity of including regular speed drills during the training cycle, even in a group of elite snow athletes.

CONCLUSIONS

To conclude, elite snow athletes capable of sprinting faster, jumping higher and producing higher values of mean propulsive power in JS are more efficient at changing direction. Since COD speed ability has a determinant role in snow athletes' performance, it is strongly indicated that coaches and fitness coaches involved in these sports consider plyometrics, power-oriented training sessions and regular sprint training as important components of their cycle-training plans. Furthermore, from a practical point of view, the use of simple and timesaving jumping tests to monitor changes in COD speed (and, consequently, specific snow sports performance) is encouraged by the strong correlations presented herein. This information may be very valuable for elite snow athletes, especially during the phases when they have to train in non-snow environments.

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