

# MASTEROPPGAVE

MKI210

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Load variability in explosive strength training, an investigation on how variability in a single exercise will affect strength and endurance in XC-skiing.

Variabilitet i eksplosiv styrketrening, en undersøkelse av hvordan variabilitet i en treningsøvelse vil påvirke styrke og utholdenhet i langrenn.

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## ABSTRACT

**Purpose:** Force and velocity are two components that are manipulated in strength training; there are different views on the effect of specificity and variability affecting these two components. The aim of the experiment was to examine the effects of training explosive strength as a supplement to ordinary cross-country (XC) training, either with the same load in each workout or with variability in the load throughout the training period. In addition, we aimed to investigate whether the effect of added explosive strength training in a double poling exercise contributes with a transfer effect to a performance test in double poling (DP).

**Methods:** 35 subjects ( $18.6 \pm 0.8$  years,  $180.6 \pm 5.0$  cm,  $74.0 \pm 6.7$  kg) competing at a national level in junior XC skiing were divided into two different experimental groups and one control group following results in the pre-test. An eight-week training period was performed with a post-test in the end of the training period. The experimental groups consisted of a variable group who trained with variability in load and repetitions in each session, while a repetitive group exercised the same load and number of repetitions. The control group performed normal training for an XC skier.

**Results:** Pre-test performances were similar between the groups. When the variable group increased the number of workouts, the increase in a double poling performance test correlated significantly. The repetitive group showed significant strength enhancement in the training exercise with increased number of workouts. The control group showed no significant differences between tests.

**Conclusion:** Additional strength training with an exercise that resembles the DP technique will improve performance in a DP time trial more than not performing added strength training. For the repetitive strength-training group there was correlation between the number of strength-training workouts, and the increase in power output in the workout exercise. Moreover, increasing the number of strength workouts in training with variability correlated with performance in the DP time trial.

**Key words:** Variability, repetitive training, specificity, transfer, velocity, explosive strength, double poling and XC-skiing.

## SAMMENDRAG

**Hensikt:** Kraft og hastighet er to komponenter som blir manipulert i styrketrening, det er ulike syn på hvilken virkning spesifisitet og variabilitet påvirker disse to komponentene. Denne undersøkelsen har til hensikt å undersøke effekten av eksplosiv styrketrening med variabilitet i motstand versus trening med samme prosentvise vektbelastning i hver økt. All styrketrening ble gjennomført som et supplement til ordinær langrennstrening. I tillegg ble det undersøkt om effekten av eksplosiv styrketrening i en stakelignende øvelse gir en overføring til en utholdenhetstest i staking.

**Metode:** 35 forsøkspersoner ( $18,6 \pm 0,8$  år,  $180,6 \pm 5,0$  cm,  $74,0 \pm 6,7$  kg) som konkurrer på et nasjonalt juniornivå i langrenn ble delt inn i to forskjellige eksperimentelle grupper og en kontrollgruppe matchet etter resultater i pre-test. En åtte ukers treningsperiode ble gjennomført, med en post-test etter endt treningsintervensjon. De eksperimentelle gruppene ble delt inn i en variabilitetsgruppe som trente med variabel vektbelastning og repetisjoner fra økt til økt, og en repetisjonsgruppe som trente med identisk vektbelastning, serier og repetisjoner i hver økt. Kontrollgruppen trente kun ordinær langrennstrening.

**Resultater:** Før treningsperioden begynte var det ingen forskjeller mellom gruppene. Etter treningsperioden var det signifikant korrelasjon mellom prestasjonsforbedring på staketesten og antallet gjennomførte treningsøkter for variasjonsgruppen. For repetisjonsgruppen ble det funnet signifikant korrelasjon mellom antall gjennomførte treningsøkter og styrkeframgang på treningsøvelsen. Kontrollgruppen hadde ingen signifikante forskjeller mellom testene.

**Konklusjon:** Ekstra styrketrening med en øvelse som ligner staketeknikken, vil forbedre prestasjonen i et staketestløp. Gjentatt repetitiv styrketrening vil øke styrken signifikant i treningsøvelsen når antall treningsøkter øker. Desto flere styrketreningsøkter med variabilitet korrelerer med prestasjonsforbedring i en utholdenhetstest i staking.

**Nøkkelord:** Variabilitet, repetitiv trening, spesifisitet, transfer, hastighet, eksplosiv styrke, staking og langrenn.

## Table of contents

ABSTRACT .....	1
SAMMENDRAG .....	2
Table of contents.....	3
Introduction.....	4
Methods.....	8
Experimental approach to the problem.....	8
Subjects .....	8
Test procedures.....	9
Test 1: Peak power and time to peak power .....	9
Test 2: Progressive power .....	10
Test 3: DP time trial, 4.3 km .....	11
Training procedure .....	11
Statistics .....	12
Results .....	13
Discussion .....	16
Variability.....	16
Variability versus specificity .....	17
Study limitations .....	18
Conclusion.....	19
Practical applications.....	19
References.....	20



## Introduction

Cross-country (XC) skiing is a popular winter sport. Elite XC skiers perform many hours of training every year; among 85-90 % of 750-950 hours of annual training is endurance training (Sandbakk, 2018; Sandbakk & Holmberg, 2017). Their strength training includes maximal strength, power and submaximal exercises focusing on core stability, motor control and injury prevention (Sandbakk, 2018). During the year, most of the strength training is done in the pre-season, while in season they usually include some training with the aim of maintaining strength. When the aim is to improve in a skill where strength is a decisive feature, knowledge about the type of strength and how to perform the training is essential. Training is guided by different training principles where overload, variability, specificity and individualization are significant (Zatsiorsky & Kraemer, 2006). Stone, Collins, Plisk, Haff, and Stone (2000) highlight overload, variation and specificity as the basic training principles in a practical perspective. Overload is a stimulus that forces an organism to adapt. To achieve development, the training load has to be above the habitual level (Zatsiorsky & Kraemer, 2006). Application of the principles comes with a paradox; training must be specific, but also with enough variation.

When athletes are involved in strength training, the aim is often to improve in some other areas that need strength. Consequently, transfer of strength will be of immense importance. Transfer is defined as “*the carryover of learned responses from one type of situation to another*” (“Merriam-Webster’s Collegiate Dictionary,” 2012). When training one task, another task may experience transfer and develop: It may be positive, negative, or neutral (Carroll, Riek, & Carson, 2001; Issurin, 2013; Oxendine, 1968). Therefore, how the exercise is carried out, has a vital impact on the desired outcome. The specificity of movement pattern and contraction type in strength training are both necessary to show an increase. Accordingly, strength training exercises should simulate the sport movements as closely as possible (Sale, 1988; Sale & MacDougall, 1981; Zatsiorsky & Kraemer, 2006). This was investigated in junior athletes (13-18 years) performing upper body power exercises (UBP) and the influence on race performance (Nesser, Chen, Serfass, & Gaskill, 2004). This study highlights that training on roller board with a DP motion was more effective than circuit training, a ski-specific training group, and a weight group. UBP in the roller board group could statistically account for nearly 30 % of the improvements in competitive performance. Heavy strength training performed by XC-skiers have shown improvement in work economy when the training was performed in a pull-down exercise where the thighs were locked, and

the subjects performed a simulated double poll (Hoff, Gran, & Helgerud, 2002; Hoff, Helgerud, & Wisløff, 1999; Østerås, Helgerud, & Hoff, 2002). Losnegard et al. (2011) report that maximal strength training consisting of standing pull-down, seated pull-down and triceps press exercises effects upper body power for XC skiers, they show that strength training improves  $VO_{2max}$  in both a skate roller-skiing and a double poling performance. Several studies experience improvements in performance when movement patterns are similar to the exercises intended (Blazevich & Jenkins, 2002; Murray et al., 2007; Nesser et al., 2004; Pereira & Gomes, 2003; Sale, 1988; Sale & MacDougall, 1981). In XC imitating the technique while performing the strength exercises may do this. When considering the DP-technique, the athlete must spend as much force as possible, the movement velocity must be equal, and the muscles involved must be similar to the original technique. Behm and Sale (1993a) argue that the intention of doing the contraction rapidly also plays an influential role, rather than just the movement velocity. Both neural and muscular adaptations might be responsible for the high-velocity training response. Moreover, they also show that the increase in strength were highest at training velocity, which implies muscular adaptations as well. Theoretically, transfer has been studied for over a century and Thorndike's "identical elements theory" expresses specificity (Adams, 1987; Rose & Christina, 2006). He studied bilateral transfer, where he found that similar movements or tasks did transfer to opposite hand or foot. Oxendine (1968) explains the size of specificity when he says: "*the mental processes which have the same cell action in the brain as their physical correlate*". In this perspective performing strength training where the objective is to improve DP in XC-skiing, the exercise has to imitate the technique in movement pattern, velocity and load. Stone et al. (1998) explain that the more similar a training exercise is to the actual physical performance; the probability of transfer is higher. According to Issurin (2013), athletes can positively transfer increased strength abilities to their technical skills when performing the training sport-specific, and Sale and MacDougall (1981) say there is a specificity of velocity training effect, where the specificity is related to the organization of movements by the brain rather than to selective recruitment of muscle unit types. If the strength exercise hinders or interferes with DP, negative transfer may appear (Magill, 1998). Recommendations in strength training for XC-skiers suggest that heavy strength training has to be movement specific (Sandbakk, 2018). Ultimately, training transfer determines how useful each given exercise is for the targeted athletic performance (Issurin, 2013).

Periodized strength training refers to planned changes in any of the acute training

program variables, to bring about continued and optimal fitness gains (Fleck & Kraemer, 2014). It may involve strength, power, motor performance, and/or muscle hypertrophy. Variability of training involves periodization, with different training in different periods. The double pole-technique (DP) in XC skiing must be executed with different speeds given the terrain. In a study of male college students by Toji and Kaneko (2004), the increase in maximal power was significantly correlated with the increase in velocity, suggesting that an increase in maximal power may be associated with training with various velocities. Therefore, to improve in the different parts of the technique, the training may benefit from variability. Bompa (1999) implies variability helps preventing monotony and boredom, and that the principle may be used to alter the overload stimulus. Manipulation of volume, intensity, speed of movement, rest periods and exercise selection are possible ways to increase the variability in strength training (Fleck, 1999; Stone et al., 2000), and planned variation could help the athlete remain in a relatively non-fatigued state during the training program (Stone et al., 1998). If this is the case, the athlete may increase the stimulus to reach higher levels of overload and avoid overtraining. In XC, better skiers use a DP strategy that gives higher pole force (Holmberg, Lindinger, Stöggl, Eitzlmair, & Müller, 2005), and thus elite skiers control DP speed by increasing both cycle frequency and cycle length (Lindinger, Stöggl, Müller, & Holmberg, 2009). An increased pole force and reduced contact time achieves a longer rest period during the DP-cycle. General strength is proposed not to be the major determinant in elite skiers, and it is suggested that discriminating factors between faster and slower skiers are the coordination of timing and proper instant of force application (Stöggl, Müller, Ainegren, & Holmberg, 2011).

Explosive strength training targets both force and velocity. Mikkola, Rusko, Nummela, Paavolainen, and Häkkinen (2007) revealed that explosive strength training improved work economy and did not impair aerobic capacity among male cross-country skiers. The improvements were believed to result from improved neuromuscular characteristics. Østerås et al. (2002) draw a comparison between increased work economy and improved aerobic capacity. They argue that a change in the force-velocity relationship and the mechanical power output is a result of the heavy strength training with the intention of fast contractions, and thus will improve work economy. This is supported by the work of Ronnestad, Kojedal, Losnegard, Kvamme, and Raastad (2012), where the strength and economy improved whereas no change in roller ski time trial was found. Pereira and Gomes (2003) investigated the effect of different movement velocities on resistance training and they

found that some studies indicate specificity while others show generality in strength gains. Subjects used in comparable studies are often untrained college students. A generalization of these studies to well-trained athletes will be problematic. Fleck (1999) states that strength gains occur at a slower rate in highly trained vs. moderately trained subjects. Moritani and DeVries (1979) explain that early changes in strength may be due to neural factors, while hypertrophic factors may display a significantly greater contribution after 4 to 6 weeks of strength training.

The present study aimed to examine upon variability in load and velocity, and specificity when training explosive strength. The purpose of this investigation was to compare the effect of variability versus specificity in power training on elite XC skiers. In more detail, we wanted to examine differences between these two types of power training on performance changes in different strength tests and a DP test in XC skiing. In addition, we wanted to examine whether XC skiers performing power training and XC skiers performing traditional training differ in a DP endurance test. Therefore, the problems investigated are summarized in these questions:

- 1. Will additional strength training improve performance in DP time trial more than only performing training XC traditionally?*
- 2. Will variability in load in explosive strength training improve performance in DP time trial more than repetitive strength training with the same load?*
- 3. Will the number of workouts in training with variability, improve strength and DP time trial more than training without variability?*

## Methods

### Experimental approach to the problem

An experimental pre-post-test design with three separate groups was used to investigate the effect of variability versus specificity in strength training intensity in elite XC skiers. The participants were randomly assigned to three groups: control group, CG (n=10), repetitive group, RG (n=11), and variable group, VG (n=14). RG and VG performed training over an 8-week period. The independent variable was the kind of periodization and type of strength training (CG vs. RG and VG), and dependent variables were peak power, time to peak power, progressive power-test and result in a double poling time trial.

### Subjects

Forty-seven male students competing on a national level in cross-country skiing and biathlon volunteered for this project. Thirty of them fulfilled the inclusion criteria for question 1 and 2, and 25 for question 3, a total of 35 individuals ( $18.6 \pm 0.8$  years,  $180.6 \pm 5.0$  cm,  $74.0 \pm 6.7$  kg). The inclusion criteria for this study were: (a) participation in national youth competitions, (b) not to carry out other training involving the exercise of this study or familiar exercises, (c) not to carry out other upper-body heavy resistance training, (d) completing at least 12 workout sessions to be considered in question 1 and 2, and 5 sessions to be considered in question 3.

*Table 1*

	Variable group (n=14)	Repetitive group (n=11)	Control group (n=10)
Age (years)	$18.8 \pm 1.0$	$18.6 \pm 0.9$	$18.6 \pm 0.5$
Body height (cm)	$181.4 \pm 5.8$	$180.1 \pm 5.6$	$181.1 \pm 5.2$
Body weight (kg)	$72.4 \pm 5.8$	$74.4 \pm 8.3$	$76.1 \pm 5.7$

The subjects were informed both written and orally in advance and signed a written consent before inclusion in the study. The subjects accepted the criteria of no heavy resistance training of the upper body besides this study. Guidance and instructions were given all participants before they entered the training period, and a week during the intervention period. All subjects kept their own training logs. The subjects had the opportunity to withdraw from the study at any point. Group assignments were based on their scores on the pre-test in the

beginning of the intervention. Due to health problems and injuries, and failing the inclusion criteria, 17 individuals had to withdraw from the study of question 1 and 2. 30 individuals completed all the tests. Individuals who did not fulfil the inclusion criteria for question 1 and 2 in VG and RG, are included in some of the analysis for larger group comparison and fulfil the criteria for question 3, a total of 25.

### **Test procedures**

Body weight and body height were measured prior to test 1 both on pre- and post-test. Before and after the 8-week training study, the subjects performed three exercise tests: The first was peak power and time to peak power test, the second was a progressive power test, while the third was a roller ski double poling time trial.

#### **Test 1: Peak power and time to peak power**

To test peak power and time to peak power in the pull-down exercise the subjects performed with a forward leaning position. An elastic band (Kappi # 4,) is attached to the hips to prevent the subjects from falling. The test is performed in a weight machine (Impulse IT93, Impulse Health Tech Co. Ltd., UK), imitating the double poling technique in cross-country skiing (see Figure 1). Before the test, a warm-up protocol is conducted, starting with 5-10 minutes jogging or cycling, and followed by 2-3 sets with 1-4 repetitions where the load increases progressively until test load is reached. External load in the actual test was set at 50 % of pre-test body weight. The subjects have three attempts with one minute of rest in between. Both peak power and time to peak power is registered. Peak power is the highest measured watt during the test. While time to peak power is the time in hundreds of a second from the first positive change in power of more than 5 watt until the subject reaches peak power. The mean between the two best attempts is calculated and is used as the subjects' result.

A correct execution is when the candidate is standing with a shoulder-wide position in a forward leaning posture. The elastic band attached to the hip ensures that the gravitational line falls in front of the toes and keeps the subject from falling. A barbell attached to the weight machine is held in front of the head with the elbows bent 90 degrees. To start the poling, muscles in the abdomen, back and hips stabilize. The downward pull starts after a small counter-movement, then a contraction in the abdomen, followed by work in back muscles and other arm extensors.

For this test MuscleLab 4010 with a linear encoder was used to measure motion in function of time (Ergo test Innovation AS, Porsgrunn, Norway), with a sampling rate at 100Hz. The system has been validated, showing a maximal error less than 0.3 %, 0.9 % and 1.2 % for force, velocity and power respectively. Thus, the system was found to be suitable for evaluation of athletes performing specific skills (Bosco et al., 1995).

*Figure 1: The execution of the strength exercise is shown below. The start position (A), the pull down phase (B) and the end position (C).*



### **Test 2: Progressive power**

The test follows test 1 and is identical in execution of the exercise. Registration, measurement system and treatment of data are also identical. The candidates conduct 4 sets and 4 repetitions. Each set has different loads, and the load increases for each set, the first set has 20 % of body weight, the second set has 40 %, the third set has 60 % and the fourth set

has 80 % of body weight. The results are based on the mean between top two scores in each set. This again is summarized and divided on the candidate's body weight.

### **Test 3: DP time trial, 4.3 km**

A warm-up of 10-15 minutes is performed, skiing on roller skis with progressively increasing intensity. The DP-test is an undulating road test on an asphalt surface with 4.3 km, with an elevation of 170 m from start to finish. The test is carried out as a competition, starting individually with a 30 second interval, and performed using the DP-technique. Results are registered in seconds. Pre-test conditions were sunny and around 12-15 degrees Celsius with partly wet asphalt, the post-test conditions were cloudy and partly wet asphalt, 18-20 degrees Celsius. During the intervention in fall, pre-test conditions were 6-10 degrees Celsius, cloudy and dry asphalt. Post-test conditions ranged from 0-15 degrees Celsius, sunny and icy weather.

### **Training procedure**

Participants in the study are active in cross-country skiing and biathlon; therefore the intervention will be a supplementary training. The participants are divided in three groups: a variable training group (VG) with variability in repetitions, series and loads (VG), a repetitive group (RG) training with the same repetitions, series and load during the whole period, and a control group (CG). Both VG and RG must do the training 3 times a week. RG performs the training with 4 sets of 4 reps, where they execute with a load of 50 % of pre-test BW. VG has a program where sets, reps and loads vary accordingly to table 2. If they did not fulfil all training session one week, they would start on session 1 the next week. CG will not perform any training in the exercise or in any similar exercises, but perform their training in a normal manner.

Before they perform the exercise, a warm-up is needed, at least 5 minutes jogging or cycling followed by some technical repetitions. In some cases, the exercise could be done alongside other training sessions, and then they already are prepared and can start the exercise at once. Any similar exercises will not be performed during the intervention. The subjects log their training by confirming every session by a text message.



Table 2: presentation of training (number of sets, repetitions and the intended load) for the variable group (VG) during the training intervention.

WEEK	SESSION 1		SESSION 2		SESSION 3	
	<i>Sets x reps</i>	<i>Load</i>	<i>Sets x reps</i>	<i>Load</i>	<i>Sets x reps</i>	<i>Load</i>
1	4 x 4	50 %	3 x 6	30 %	4 x 4	60 %
2	5 x 3	70 %	4 x 4	50 %	3 x 6	20 %
3	5 x 3	70 %	4 x 4	50 %	5 x 3	80 %
4	5 x 3	70 %	4 x 4	60 %	5 x 3	80 %
5	3 x 6	30 %	4 x 5	40 %	3 x 6	30 %
6	3 x 6	20 %	4 x 4	50 %	3 x 6	30 %
7	5 x 3	80 %	4 x 5	40 %	3 x 6	30 %
8	5 x 3	70 %	3 x 6	30 %	4 x 4	50 %

### Statistics

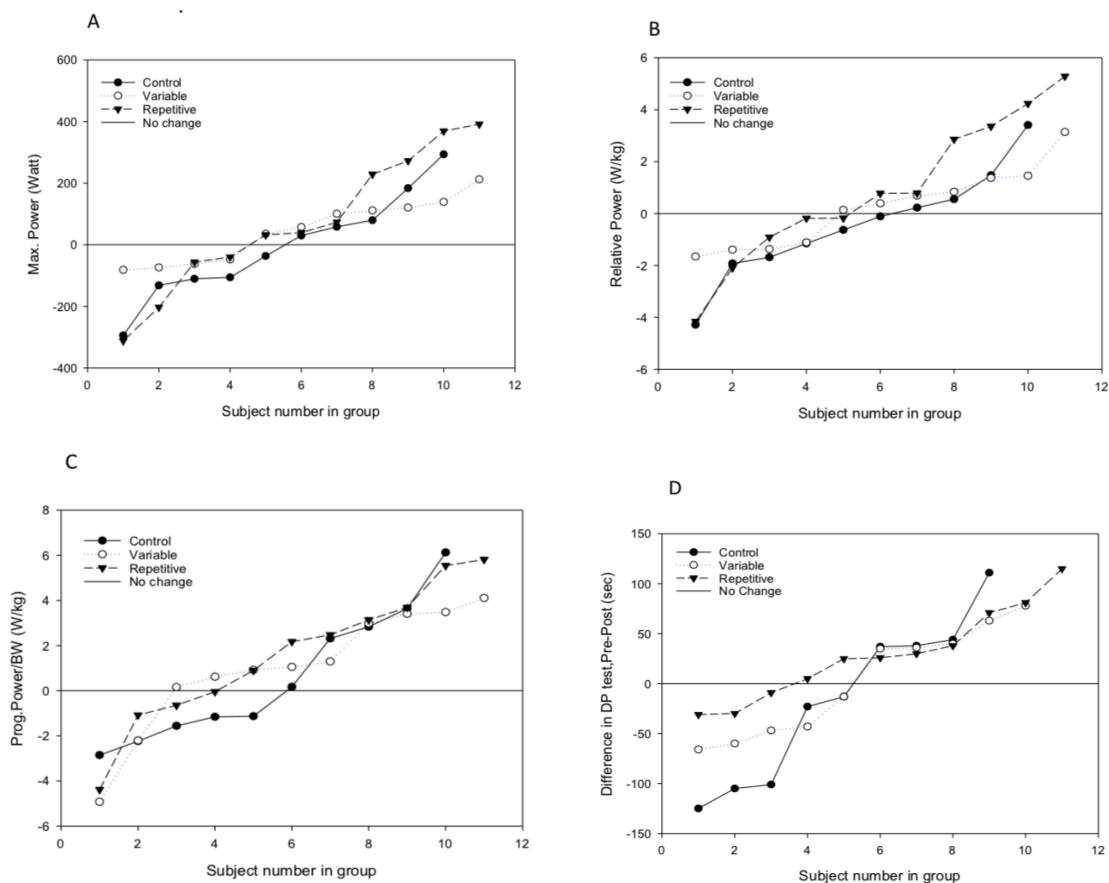
The results were registered in Microsoft Excel and analysed using IBM SPSS Version 23. Mean scores and standard deviation were calculated for every group in all tests. Each subject's score from pre- and post-test was ranked and positioned based on the development, from lowest to highest with regards to group affiliation. The scores were placed in a scatter plot, and a binominal distribution was performed to show whether the scores are positively or negatively set against the development.

The influences of the number of workouts on the test scores were calculated with Pearson's r. In these analyses the CG were excluded. RG and VG were analysed independently and together. Inclusion criteria for the correlation analysis are membership in one of two training groups, having performed more than five workouts and taking part on both pre- and post-tests. 25 subjects were included in this analysis. 14 in the VG performed strength tests, while only 13 performed the DP time trial. The RG had 11 who conducted all tests and performed training. The different test scores are correlated with the number of workouts and presented in table 3; both training groups are considered together and separately.

## Results

Overall, the training groups show a trend ( $p = 0.08$ ) toward increased peak power from pre- to post-test, while no difference appears in peak power in CG (see figure 2A). Both VG and RG consist of 11 group members, 7 out of 11 in both groups have a higher peak power in post-test compared to pre-test. Analysing the results separately for each group reveals no differences.

*Figure 2: Changes in the different tests performed: peak power (A), relative power (B), progressive power (C) and DP time trial (D). Each participant's difference is relying on group affiliation from the highest negative change to the highest positive change.*



The strength training has an impact on the development in the test. Relative power (see figure 2B) displays that 7 out of 11 in VG have a higher relative power in post-test compared to pre-test. The scores in RG show 6 out of 11 with an increase. Only 4 out of 10 in CG produce a higher relative power in post-test compared to pre-test, which is no difference. In the variable group a significant increase from pre- to post-test in progressive power

emerge, where 9 of 11 have a higher (see figure 2C) post-test result compared to pre-test results ( $p = 0.03$ ). No improvement in the same variable was found in RG and CG. When both training groups are joined, the significance strengthens ( $p = 0.02$ ), which show that the strength training increases progressive power. In DP time trial (figure 2D), 8 of 11 in RG have a shorter time ( $p = 0.08$ ), while 5 of 10 in VG, and 4 of 9 in CG improve. Considering both training groups together unveil a trend ( $p = 0.1$ ), and show that the strength training will improve a DP time trial.

*Table 3: Presentation of correlation between number of workouts and tests in the strength training groups.*

Groups	Peak power	Relative power	Time to peak power	Progressive power	DP time trial
VG + RG (n=25, 24 DP)	<b>r = 0.43*</b>	<b>r = 0.41*</b>	r = 0.23	r = 0.14	<b>r = -0.48*</b>
VG (n = 14, 13 DP)	r = 0.35	r = 0.30	r = 0.36	r = -0.13	<b>r = -0.65*</b>
RG (n = 11)	<b>r = 0.64*</b>	<b>r = 0.64*</b>	<b>r = 0.69*</b>	<b>r = 0.77**</b>	r = -0.05

\* = Significant at 0.05-level      \*\* = Significant at 0.01-level

Significant correlations between the number of workouts and the increase in peak power production ( $r = 0.64$ ) appear for RG. In addition, the number of workouts also correlates with an increase in relative power ( $r = 0.64$ ) and progressive power ( $r = 0.77$ ). However, time to peak power ( $r = 0.69$ ) increases with an increased number of workouts. After training, RG produce a higher power in all three strength tests, while more workouts result in a longer time to execute maximal power. In DP time trial there are no correlations between the number of workouts in the RG. In the VG on the other hand, only improvement in DP time trial ( $r = -0.69$ ) was found to correlate significantly with the number of workouts, while all the strength tests were not affected by increasing the number of workouts. Overall, both strength-training groups together reveal a correlation between the number of workouts and peak power ( $r = 0.43$ ), relative power ( $r = 0.41$ ) and DP time trial ( $r = -0.48$ ). However, peak power ( $r = 0.43$  vs.  $0.64$ ) and relative power ( $r = 0.41$  vs.  $0.64$ ) have less correlations

compared with RG and DP time trial ( $r = -0.48$  vs.  $-0.65$ ) have less correlation compared with VG.

*Table 4: Presentation of pre- and post-test results (mean + SD) and differences between pre- and post-test on peak power, relative power, progressive power, time to peak power and DP time trial.*

<b>Test</b>		<b>CG</b> <b>n = 10</b>	<b>VG</b> <b>N = 10</b>	<b>RG</b> <b>n = 11</b>
<b>Peak power (Watt)</b>	Pre	1824.5 (225.1) -	1682.0 (227.5)	1612.4 (331.4)
	Post	1809.9 (239.8)	1681.7 (238.7)	1684.8 (222.0)
	<b>Diff PRE-POST</b>	- 24.6	- 0.3	+ 72.4
<b>Relative power (Watt / Body weight)</b>	Pre	24.1 (2.7)	23.3 (2.8)	21.7 (4.2)
	Post	23.5 (2.5)	23.0 (2.8)	22.6 (2.1)
	<b>Diff PRE-POST</b>	- 0.6	- 0.3	+ 0.9
<b>Progressive power (Watt / Body weight)</b>	Pre	39.0 (4.3)	38.8 (3.4)	36.6 (4.0)
	Post	39.1 (3.5)	39.6 (3.3)	38.2 (3.0)
	<b>Diff PRE-POST</b>	+ 0.1	+ 0.8	+ 1.6
<b>Time to peak power (1/100 sec)</b>	Pre	20.1 (4.5)	18.6 (4.4)	19.6 (4.4)
	Post	18.4 (3.5)	20.0 (4.4)	21.0 (4.9)
	<b>Diff PRE-POST</b>	- 1.7	+ 1.4	+ 1.4
<b>DP time trial (Sec)</b>	Pre	1023.1 (88.4)	1043.8 (160.8)	1052.6 (135.5)
	Post	1038.1 (123.0)	1021.7 (142.1)	1023.5 (123.3)
	<b>Diff PRE-POST</b>	+ 15.0	- 22.1	- 29.1

## Discussion

The main findings display that load variability in strength training seems to be important in order to improve performance from strength training in a DP time trial when the number of workouts is high enough. In addition, specificity is vital to get strength improvement in a movement similar to the training exercise. When the number of workouts increases, training with load variability improves transfer to DP time trial, while repetitive strength training improves strength in a test exercise similar to the training. Performing power training as a supplement to XC seems to improve a DP time trial more than training XC traditionally.

## Variability

The majority of studies examining the effectiveness of periodized training have focused on strength/power gains and manipulated training intensity and training volume (Fleck, 1999). In this study the training volume should be equal between the two training groups, and the only real difference between the training groups is the variability of training load. The VG varied both series, repetitions and loads in training, but performed the same training exercise as RG. An interesting finding from this study was the correlation between the number of workouts and the improved performance in double poling time trial. This contrasts with the non-variable type of training in the RG, where no significant correlations were found between DP time trial and number of workouts. When endurance is the primary feature in the sport, strength training must contribute to a transfer effect. This effect may be a result of the variability in the completed training, because when VG varies the load, the velocity in each implementation will vary. Strength training may be performed with various force, RFD or velocities. However, the greatest strength gains occur at or near the training velocity (Behm & Sale, 1993a, 1993b; Cronin & Crewther, 2004; Kaneko, Fuchimoto, Toji, & Sueti, 1983). Intermediate velocity strength training impacts transfer of training to both faster and slower velocities. Activities requiring a range of movement may prefer this intermediate velocity (Bell & Wenger, 1992; Kanehisa & Miyashita, 1983). There is a relationship in a movement between force and velocity. Variability in load will alter the velocity, therefore this variability may advance transfer to a technique that alters in execution concerning load and velocity. Harries, Lubans, and Callister (2015) think variability is of importance to prevent stagnation in general and adaptation to the chosen training approach. XC skiing is performed in undulating tracks and the DP technique changes according to variation in terrain (Stöggl & Holmberg, 2016). Therefore, training with variability may be

the most specific training on behalf of the actual sport, since variation in terrain will elicit variability in velocity and force (Stöggl & Holmberg, 2016). Lindinger et al. (2009) present support for this when they displayed that elite XC-skiers alters cycle length and rhythm. In addition, Stöggl et al. (2011) stated that faster XC skiers have more altered strategies than slower skiers. Varying frequencies in training to adopt technique to varied terrain is advocated. Timing and proper use of force are more important than applying highest possible force performing the DP-technique (Stöggl et al., 2011). In strength training this may be done by altering load and hence velocity. This alteration may affect a wider range in the force-velocity curve, which is in line with the authentic performance of the DP-technique. A lower frequency might give a more beneficial effect in DP, because an increased pole force to the ground and reduced poling time will result in a longer rest period during the DP-cycle (Lindinger et al., 2009).

Both training groups improve more than CG in DP time trial. Earlier studies suggest that maximal strength will improve work economy. Both training groups together show a reduced time in DP time trial when the number of workouts is accounted for. These groups decreased their mean time, while the CG increased their mean time. Moreover, only VG has a significant correlation between DP time trial and number of workouts. The variability in the VG's strength training may respond with a superior improvement in technique and a better transfer effect.

### **Variability versus specificity**

RG improves peak power 4.5 % and progressive power 4.4 % from pre- to post test, the tests resemble their actual training. Strength enhancements for RG increase when the number of workouts increases. This indicates that specificity is of importance, especially in developing the actual feature. Support for this may Sale and MacDougall (1981) express, they show that movement pattern, velocity, contraction, and contraction type are important in strength development. This is in line with research where there are proposed that the movement pattern needs to be similar (Blazevich & Jenkins, 2002; Murray et al., 2007; Nesser et al., 2004; Pereira & Gomes, 2003; Sale, 1988). RG show the highest increase in the test, which is most specific to their training, while VG improve most in DP time trial. Peak power improves significantly from pre- to post-test for RG, where the test exercise is exactly similar to the training performed. VG improve significantly only in DP time trial. Training with variability may resemble a DP time trial, and lead to more specific training considering a

transfer effect from strength to endurance. McBride, Triplett-McBride, Davie, and Newton (2002) show that different velocities and loads are important in the improvement of distinct phases in an exercise. The velocity will alter through the execution of an exercise; heavy resistance training is effective at increasing initial acceleration while the movement velocity is slow, although light resistance training increases acceleration capabilities during the higher velocity component of the movement (Morrisey, Harman, & Johnson, 1995). Both training groups perform the exercise similarly and with the same training volume; the only difference is the training load and velocity of movement.

RG performs the training exactly similar to peak power test every time and has several workouts at the same intensity. On the other hand, VG has only a few workouts totally on the specific intensities, which may explain the lack of strength development. Increasing number of workouts strengthens the effect of higher transfer of performance from variable strength training to DP time trial for VG. Progressive power is more similar to the training of VG, with the variation of load. There is support of this exercise-type specificity from studies stating that the greatest effects occur when the same exercise type is used for both testing and training (Morrisey et al., 1995; Sale & MacDougall, 1981). The training exercise chosen for this study resembles the DP technique in XC. Training with load variability will influence changes in the force-velocity relationship, and may be the reason why the variable training is more effective regarding transfer. To experience transfer the strength training must simulate the sport movements as closely as possible (Sale, 1988; Sale & MacDougall, 1981; Zatsiorsky & Kraemer, 2006). An increased number of workouts on the different loads might be required to improve in strength, and VG may have too few workouts with the exact same training load to improve strength in a specific exercise with a specific load. When the load is lighter, each single repetition is performed faster. Increasing number of repetitions to even the load will increase the total tension time. And time under tension is probably an important factor (Cronin & Crewther, 2004). Jones, Bishop, Hunter, and Fleisig (2001) recommend specificity of training velocity; the load has to be adjusted to fit the execution of the exercise. Training with variability could improve various parts of the execution and the technique itself.

### **Study limitations**

Testing athletes in outdoor environment presents surroundings that are difficult to control. To avoid differences in outdoor test conditions, test groups were organized with members from all three groups. The time of execution of the post-test was planned according

to the weather. The participants involved performed the training as a supplementary training; other activities may have affected the quality and outcome of training. Age and how many years experience with strength training are also variables that might influence the outcome, while concurrent training and large volume of endurance training may hinder strength improvements. Random distribution of participants tries to avoid bias regarding age, performance and anthropometric differences between subjects.

### **Conclusion**

Performance on a DP time trial will be positively affected by explosive strength training in an exercise similar to the DP technique. Group differences are not influenced whether the training is performed repetitive or with variability. Training with variability increases the improvements in a DP time trial significantly with added number of workouts. On the other hand, increasing the number of workouts with repetitive training will significantly improve all strength tests.

### **Practical applications**

In most sports explosive strength is an important part of performance. This study shows that training one additional exercise three times a week with high degrees of specificity will improve the results in an endurance test and strength tests. Increasing number of workouts will give a transfer effect when training with variability in load, while training with repetitive load will give enhancement in the strength exercise. This study brings a perspective about how specificity and variability in training contribute to improvements in strength and DP time trial in XC skiing.



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