NORWEGIAN SCHOOL OF SPORT SCIENCES

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Placebo and Nocebo in Sports: Potential Effects of Hypothetical Differences in Roll Resistance on Roller Ski Performance

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Department of Sport and Social Science
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Forord

Jeg har vokst opp med utholdenhetsidretter som langrenn, sykling, løping og orientering som en del av hverdagen min. Selv om orientering nå er hovedidretten min, har jeg hatt stor interesse og lenge vært involvert i langrennssporten både som utøver og trener. Orientering er en idrett hvor utstyret i seg selv er av liten betydning for prestasjonen (i hvert fall i forhold til idretter som sykling og langrenn). Jeg har ofte tenkt over om dette fokuset på utstyret har vært med på å påvirke valget mitt om å satse på orientering framfor langrenn eller sykling. Følger man med på internasjonal langrenn på TV hører man utøverne regelmessig uttale seg om hvordan skia var med på å påvirke prestasjonen. Takketaler til «gutta i smørebua» etter et vellykket renn er trolig med på å forsterke et bilde om at utstyret spiller en helt vesentlig rolle for prestasjonen i langrenn. Men er det bare utstyret i seg selv som sørger for prestasjonsforskjeller, eller er det også det fokuset man har på utstyret og den rene tanken om å ha bedre eller dårligere utstyr enn konkurrentene som gjør noe med prestasjonen? Om slike placebo og nocebo effekter gjennom forskjeller i materialet i langrennssporten eksisterer er det grunnleggende spørsmålet i denne oppgaven. Det har vært en spennende prosess å lage et eget studiedesign som skulle etterlyse disse effektene i langrenn. Jeg vil takke mine veiledere Frank Eirik Abrahamsen og Thomas Johansen Losnegard som bistod med gode råd og hjelp med utarbeidelsen til både studiedesign og analyser av resultatene. Min søster vil jeg takke for nyttige samtaler og gode råd underveis i skriveprosessen av oppgaven. Til slutt ønsker jeg å takke mine foreldre for at jeg fikk vokse opp i et miljø med fokus på idrettsglede. Jeg er glad for at jeg hadde muligheten til å prøve ut mange forskjellige idretter uten å føle noe utstyrspress gjennom ungdomsårene mine.

Den aktuelle Covid-19 situasjonen har ikke hatt noen betydelig påvirkning på denne oppgaven. Datainnsamlingen ble avsluttet før nyttår, og stenging av fasilitetene på Norges Idrettshøgskole hadde ikke noen stor påvirkning på skriveprosessen. Kommunikasjon med veilederne foregikk via epost og telefonsamtaler.

Bojan Blumenstein
Norges Idrettshøgskole, Oslo, mai 2020

Summary

Introduction: Although the placebo and nocebo effects of ergogenic aids are acknowledged as a significant factor for sports performance, little is known about the effects of different sports equipment. Therefore, we examined how athletes' belief about their sports equipment affected their skiing performance in a short time trial, together with their subjective experience of the performance.

Method: In a randomized controlled trial with crossover design, 21 junior cross-country skiers completed a repeated straight 45 m indoor double poling protocol. All trials were performed on roller skis with the same roll resistance. For the baseline trial, the skis were marked with "medium roll resistance". For the experimental trials, the athletes were randomized into two groups and were given a set of new roller skis, marked as "low roll resistance" (placebo), and "high roll resistance" (nocebo). The time for each individual trial was measured with photocells, while post-experimental questionnaires examined the skiers subjective rating of the performance.

Results: The mean speed was the same for the placebo and baseline trials. However, the mean speed for the nocebo trial was slower compared to the baseline trial (mean ±95 CI; -0.7% ± 0.4%, $P < 0.002$). The subjective experience of the roller skis used during the experimental trials was different to that of the baseline trial (placebo: $P < 0.001$; nocebo: $P < 0.002$).

Conclusion: Our findings reveal that athletes' negative belief of their sports equipment influenced performance negatively. In sports such as cross-country skiing, where equipment is vital, it is advised that the negative psychological effects should be mitigated by downplaying the importance of equipment on overall performance.

Contents

1. Introduction

In the field of medicine, the existence of placebo and nocebo effects are well studied (Frisaldi et al., 2015). While the placebo effect describes a positive outcome resulting purely from the belief that one has received a beneficial treatment, the nocebo effect is a negative outcome from the belief that one has received a harmful treatment (Frisaldi, Piedimonte, & Benedetti, 2015).

When it comes to the field of sport, in addition to qualitative research and anecdotes from elite athletes (C. J. Beedie, 2007), there are over 30 studies with experimental designs throughout the last two decades. However, as most of these studies involved placebo and nocebo effects of ergogenic aids, studies focusing on sports-equipment are lacking (Hurst et al., 2019). In sports such as skiing, the waxing, structure, and quality of the skis have a major impact on performance (Sandbakk & Holmberg, 2017). However, to date, little is known about how placebo and nocebo effects influence performance in such sports.

This study was designed to examine whether hypothetical differences in the quality of cross-country skis can trigger a placebo and/or nocebo effect in junior cross-country skiers. Furthermore, we were interested to investigate whether a false belief about the rolling resistance of the roller skis could affect the athlete's subjective experience of the equipment.

More specifically, the present study used a randomized controlled trial with cross-over design and post-experimental questionnaires to test three hypotheses:

- First, subjects executing the task with the placebo intervention will perform better when compared to the baseline trial.
- Second, subjects executing the task with the nocebo intervention will perform worse compared to the baseline trial.
- Third, subjects' false belief about their equipment will change their subjective judgment about their performance after the trial.

Note: This master thesis consists of two parts. The first part goes through the theory around placebo and nocebo effects and the methodic that was used for the study. The formation of this part follows the guidelines from the Norwegian School of Sport Science. The second part is an article that is send in and currently under submission for the *Scandinavian Journal of Medicine & Science in Sports.* The formation of this article follows the authors guidelines from the Journal.

2. Theory

2.1 The Mechanisms of Placebo and Nocebo Effects

2.1.1 Defining Placebo and Nocebo Effects

In the 1960s, the first biological studies with placebo-effects were executed on animals, while experimental research on humans started in the late 1970s. Placebo research nowadays is a complex field that includes both biological and psychological investigations.

The classical definition of placebo-effects involves a symbolic significance that one attributes to an event or object in a healing context and leads to a change in the body-mind unit (Miller & Brody, 2011). While placebo effects refer to positive effects, the mechanism of the nocebo effect will have a negative influence in the healing context (Frisaldi et al., 2015).

2.1.2 Modulating factors of Placebo and Nocebo Effects

In the field of medicine, the placebo- and nocebo-effects are well studied. Due to the complex set of psychological states that vary from patient to patient it is difficult to be certain how strong these effects really are (Frisaldi et al., 2015). The appearance of the medication itself (e.g. color, shape, taste, smell), the environment (e.g. hospital, home, outside), the interference with the health professionals (e.g. attitudes, behavior, communication) and many more factors will influence the placebo and nocebo effects (Frisaldi et al., 2015). A placebo injection will, for example, have a stronger effect than a placebo pill. Differences due to genetics also exist, where some individuals can be classified as more inclined placebo responders than others (Benedetti, 2014).

2.1.3 Approaches to explain Placebo and Nocebo Effects

Different psychological and biological approaches have been proposed to explain the mechanism of placebo and nocebo effects. The main psychological factor that explains the placebo and nocebo effects centers around expectation (Frisaldi et al., 2015). A patient receiving a placebo pain-reducing injection will have an expectancy that makes him anticipate a positive (or negative) outcome about the injection (e.g. the reduction of

pain). Different cues from the environment, the patient's emotional arousal, and the interaction with the care provider will form this anticipation. The process of anticipation triggers internal changes in the patient (e.g. the release of endorphins in the brain). Other neurotransmitters that are activated by placebos are endocannabinoids and dopamine (Benedetti et al., 2016). Also, the level of prostaglandins (which increase the sensitivity to pain) seems to be reduced through placebo treatments. Patients treated with a placebo medication also have a reduced activity in areas of the brain involved in processing pain (Wager & Atlas, 2015). These biochemical pathways are the same as the ones modulated by pharmaceutical drugs (Benedetti et al., 2016). Getting a treatment might also lead to a decreased anxiety level. A study has shown that a decreased anxiety level correlates with pain relief in irritable bowel syndrome patients (Vase, Robinson, Verne, & Price, 2005). Next to the expectancy a patient can have about a medication or a treatment, factors such as desire, self-efficacy and reinforcing feedback will modulate placebo and nocebo effects (Price, Kandzari, & Teirstein, 2008). A patient that for example gets a pain reducing placebo medication might look for any signs of pain-reduction. These signs might be seen as evidence for that the treatment is successful, while negative evidence will be discarded.

These psychological and biological mechanisms might explain why a placebo pain-reducing injection can be as effective as 6-8 mg of morphine (Levine, Gordon, Smith, & Fields, 1981).

2.1.4 Learning effects from Placebo and Nocebo treatments

Another psychological mechanism that might play a role in placebo effects is learning. Experimental evidence shows that based on previous experimental research patients will learn to associate a certain medication or treatment to a specific therapeutic outcome (Colloca & Miller, 2011). When a patient has learned through repeated treatments, that a certain treatment is working, the neurochemical pathways might override conscious expectations. In that way a patient will still get a positive result of the treatment even if he/ she knows that the treatment is a placebo medication (Schafer, Colloca, & Wager, 2015).

2.2 Placebo and Nocebo Effects in Sports

2.2.1 Former Research on Placebo and Nocebo Effects in Sports

While the evidence for the existence of placebo and nocebo effects in the field of medicine is strong, we can also find similar results in the field of sport science. It is for example well studied that placebo effects and a change of belief and motivation exist when it comes to the distribution of a hypothetical ergogenic aid. In sports literature we can find plenty of anecdotes where athletes tricked themselves, or got tricked by their coaches, advertisement or other people they trusted in to belief that certain nutrition or other hypothetical performance enhancing substances will help them perform better (C. J. Beedie, 2007). Qualitative data shows that this change in belief most likely had an impact on the athletes' performance (Christopher J. Beedie, Coleman, & Foad, 2007).

Throughout the last two decades, we can find 31 experimental studies performed on placebo effects in sports. 20 of these are done on nutritional ergogenic aids like caffeine, fictious supplements or forbidden substances like anabolic steroids. From these studies we know that banned performance enhancing substances like hypothetical anabolic steroids seem to have the largest effects (Hurst et al., 2019). 12 studies are focusing on mechanical aids like kinesiology tape, magnetic wristbands or cold-water immersions (Hurst et al., 2019). Only three of the 31 experimental studies include nocebo effects (all done on ergogenic aids). Two of these studies had a similar experimental design to our study. Both studies tested the placebo and nocebo effect in a respectively 20-m and 30-m repeated sprint protocol (running). Both studies found a significant nocebo effect (-0.9%; -1.7%), but no placebo effect (Christopher J. Beedie et al., 2007; Hurst, Foad, Coleman, & Beedie, 2017).

As mentioned before will for example a pain reducing injection have a bigger placebo effect than a pain reducing pill (Frisaldi et al., 2015). Similar differences in placebo effects are also found in the field of sports. A hypothetical forbidden substance like anabolic steroids for example will have a bigger placebo effect than a legal ergogenic aid (Hurst et al., 2019).
Despite knowing from certain material-based sports like cross-country skiing, that the sports material itself can have a huge impact on performance, we can hardly find any relevant studies focusing on the placebo and nocebo effect of sports material. The only

experimental study performed on the sports equipment itself in tennis. The study showed that a modified tennis racket (whether real or placebo) will improve your mean tennis serve performance by 5.6% (Aymeric, Cyril, Simon, Sylvie, & Isabelle, 2012). However, this study did not include nocebo effects. It remains therefore unclear if having worse equipment than your opponent will produce a negative placebo effect (or "nocebo effect"), and therefore be harmful for the athletes' performance and motivation.

2.2.2 Fluorinated skiing waxes as a potential source of Placebo and Nocebo Effects

Fluorinated skiing waxes have been used to reduce ski-snow friction in cross-country skiing for decades. They avoid dirt from entering the ski-sole and therefore contribute to a significant improvement of ski-snow friction (Kuzmin & Tinnsten, 2006). From July 2020 the production of these fluorinated waxes will be forbidden by EU-law (Comission, 2019). From the winter season 2020/21 fluorinated waxes are banned by the FIS in all skiing sports (FIS, 2019) due their negative impact on the environment (Astrup Jensen, Brunn Poulsen, & Bossi, 2008; Randi et al., 2019) and human health (Kvalem et al., 2020; Sørli et al., 2020). As we know from earlier research on ergogenic aids that forbidden substances like anabolic steroids seem to have the largest placebo effect (Hurst et al., 2019), we can act on the assumption that the ban of fluorinated skiing waxes might contribute to a reinforcement of placebo effects.

Fluorinated waxes are extremely expensive compared to normal waxes (Astrup Jensen et al., 2008). Thus, material costs might lead to major advantage for the affluent classes in society and to loss in motivation for athletes with less monetary means. The difference in price between fluorinated skiing waxes and usual skiing waxes might also reinforce placebo effects. It is for example documented that hypothetical expensive products like high-priced wine (whether real or placebo) will change the subjects experience, for example an increased report of flavor pleasantness (Plassmann, O'Doherty, Shiv, & Rangel, 2008).

Besides the potentially direct increase of performance with expensive and better equipment like fluorinated skiing waxes, it is of interest to increase knowledge about whether athletes' beliefs and changes in self-efficacy might affect performance indirectly also.

2.2.3 Potential Effects on Motivation and Sports-participation

If the athletes' change in belief would have an impact on the athletes' performance (or the subjective experience of their performance), the athletes' mastery experience will change. A significant change in once mastery experience might again have an impact on the general motivation for sports-participation (Bandura, 1997).

Assuming there are as many athletes that think positively about their material as athletes that think negatively in one competition, we can imagine three scenarios:

1. Placebo effects and nocebo effects do not exist or compensate for each other. In this case the focus on sports material would not play a significant role for the overall performance, mastery experience and motivation.
2. Placebo effects are stronger than nocebo effects. In this case reinforcing the focus on sports material as a relevant factor for performance would be beneficial for the overall performance and lead to an increase in mastery experience and overall motivation.
3. Nocebo effects are stronger than placebo effects. In this case reinforcing the focus on sports material as a relevant factor for performance would be harmful for the overall performance and lead to a loss in mastery experience and overall motivation.

3. *Method*

3.1 Ethical Considerations

The study followed the ethical guidelines of our institution and had full approval of the ethics committee of the Norwegian School of Sport Science. The participants in this study gave their informed consent to take part in this study (attachment 2). The experimental protocol was similar to speed training that the athletes are accustomed to as part of their weekly training. After the study, the participants were debriefed about the true purpose of the study and allowed to ask questions, which were answered to the best of the researcher's knowledge.

3.2 Subjects

The sample included 21 junior athletes (15 male and 6 females; mean age 17.1 ± 0.9 years) from sports including cross-country skiing and biathlon who agreed to participate in the study. The subjects were all students at a Norwegian sports school and were engaged in regular training (daily), all performing at a high national level. The subjects were randomly assigned to two groups, although we checked that there was no group difference according to gender, age, or main sport. The difference between the groups was that the placebo and nocebo intervention were executed in a different order. For Group 1 the order of trials was 1st baseline-trial, 2nd placebo-trial, 3rd nocebo-trial and for Group 2 the order was, 1st baseline-trial, 2nd nocebo-trial, 3rd placebo-trial).

3.3 Materials

Location: To avoid external disturbing factors like the weather, the experiment was performed in an indoor hall at the Norwegian School of Sport Science. A straight 45m course was marked at the long side of the hall. After the finish line there were 20m left for the subjects to break down the speed or turn to the side. At the end of the hall a thick mattress was put up for safety reason, in case of a subject failing to break down the speed after crossing the finish line. A more detailed illustration about the setup is illustrated in figure 2 under "procedure".

Roller skis: We used new standardized roller skis for classic-style skiing (Swenor Classic Elite; wheel type 3). The roller skis were from the same production series. After testing 10 pairs of roller skis in a standardized friction test on a treadmill (towing test) as described by Losnegard, Myklebust, & Hallén, 2012, we were able to establish the 2 pairs of roller skis that deviated the most from the mean rolling resistance. The remaining 8 pairs of roller skis used for the experiment demonstrated no significant difference in rolling resistance. Two pairs of roller skis were used for the placebo condition, four were used for the baseline condition and two were used for the nocebo condition. Statistical post-experimental analysis revealed that the measured rolling resistance of the roller skis used during the trials had no significant correlation with the time the subjects used during the trial ($R = -0.033$). For this reason, the effect of the measured rolling resistance on performance was considered non-existent and was therefore not included in further analysis. Even if the rolling resistance was the same for every pair of roller skis used for the experiment, the numbers that were written on tape stripes on top of the roller skis that indicated a hypothetical rolling resistance (1 = low (placebo), 2 = medium (baseline) and 3 = high (nocebo)) were visible to the subjects.

Poles: Cross country skiing poles (Swix Sport AS, SWIX Triac 2.0, Lillehammer, Norway) with a custom-made rubber cap for indoor use were distributed to the subjects appropriate to their height (approximately 84% of body height).

Shoes: Subjects used their own skiing shoes (classic style).

Warming locker: Roller skis not in use during the running trial were kept in a warming locker (Swix Sport AS, Warmbox T007680- 110, Lillehammer, Norway). The warming locker maintained a steady temperature of 60 °C to keep the rolls at the same temperature. This was to avoid a change in rolling resistance that can occur between cold and warm rolls (Losnegard et al., 2015).

Start position: The starting position was standardized with tape markers on the ground 20 cm before the starting laser cell, as shown in figure 1. Both, the starting line and finish line had to be crossed with both feet on the same length.

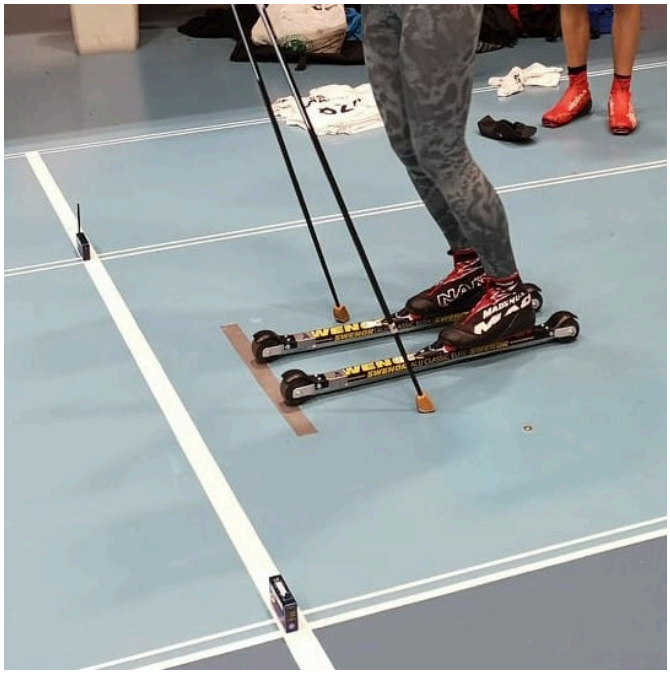

Figure 1: *Standardized starting position*

Time keeping: Time was recorded by timekeeping laser cells (Portable Brower Speed Trap II, Brower Timing Systems, Utah, USA) to the nearest 0.01 s.

Questionnaire: Questionnaires were designed to investigate whether the roller skis used in the previous trial felt different in speed compared to the roller skis from the baseline trial. In the questionnaire the subjects could tick off one of the five possible answers as shown in Table 1 (attachment 1).

Table 1: *Questionnaire to identify the subjective experience the subjects had with the roller-skis during the trial.*

How did you experience the speed of the roller-skis compared to Trial 2?					
Trial 3	□Much slower >5%	□A bit slower 2-5%	□No difference	□A bit faster 2-5%	□Much faster >5%
Trial 4	□Much slower >5%	□A bit slower 2-5%	□No difference	□A bit faster 2-5%	□Much faster >5%

3.4 Procedure

The procedure is provided in table 2 and the setup for the trials is illustrated in figure 2.

3.4.1 Warm up

All subjects started with a 20 min warm-up under the guidance of one of the coaches from the sports school. The warm-up was designed to warm up the specific muscle groups used under a classic sprint on roller skis.

3.4.2 Introduction to the task

After the warm-up subjects met with the scientists for a short briefing session about the study. During the briefing session, subjects were introduced to a "cover story" to avoid revealing the true purpose of the study: For this purpose, subjects were told that the difference between the roller skis was their rolling resistances (low, medium, and high). Accordingly, the difference in rolling resistance (according to the producer and marketing experts in the field of roller skis (Oslo Sportslager, 2013)) was stated as being 4%–6% between each of the categories (even though it actually was the same for each roller ski). The subjects were encouraged to perform an all-out sprint for each trial, regardless of which type of roller ski they were using. Only double poling technique was allowed and the finish line was supposed to be crossed with both feet on the same length. Out of the standardized starting position as shown in figure 1 the subjects could start themselves in a 10s window.

3.4.3 Customization to the task

For subject to become accustomed to the equipment and the task, a test trial (trial 1) on roller skis marked with number "2" (hypothetical medium rolling resistance) was executed by every subject. No time was recorded for the test trial.

3.4.4 Baseline trial

After a break of approximately 4 min, groups 1 and 2 started with the baseline trial (trial 2). As a baseline every subject performed an all-out sprint on roller skis marked with number "2" (hypothetical medium rolling resistance).

3.4.5 Experimental trial

The third and fourth sprint were performed on roller skis with respectively hypothetically low rolling resistance (roller skis marked with the number "1" – placebo) followed by high rolling resistance (roller skis marked with the number "3" – nocebo) for Group 1, and accordingly the other way around for Group 2. Between each trial, the subjects had a 4 min break.

3.4.6 Questionnaires

After both experimental trials (trial 3 and trial 4), the subjects completed the questionnaire about their subjective experience using the different type of roller skis (see Materials section). After all subjects had performed all sprints and filled out the questionnaire, they were taken for a short debriefing session, where the true nature of the study was revealed (see Ethical Considerations).

Table 2: *Test protocol*

	Group 1	Group 2
Trial 1	Warm up, briefing session and test trial	
Trial 2	Baseline (roll 2)	Baseline (roll 2)
Trial 3	Placebo (roll 1)	Nocebo (roll 3)
	Questionnaire	
Trial 4	Nocebo (roll 3)	Placebo (roll 1)
	Questionnaire	
	Debriefing session	

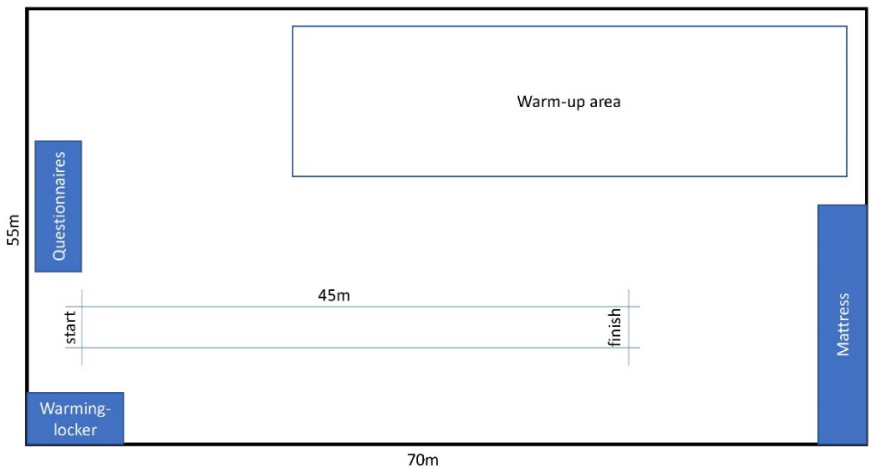

Figure 2: *Setup for the trials*

3.5 Statistical Analyses

All descriptive data are presented as mean ± SD. Data representing relative differences are presented as mean ± 95% confidence interval (CI). One-way ANOVA analyses were used to detect statistical differences between baseline, placebo, and nocebo groups. Bonferroni post hoc analyses (multiple comparisons) were used to compare the time used for the trials depending on the answers given in the post-trial questionnaires. Paired t-tests were used to investigate differences in the subjective experience of speed between the experimental trial and the baseline trial. A P-value of < 0.05 was considered statistically significant. All analyses were conducted using Microsoft Excel and SPSS software.

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Attachments

3.6 Attachment 1:

Spørreskjema SWENOR rulleski.

Startnummer: ____ Kjønn: □ m □ f Alder:___

Test 2: Hvordan opplevde du rulleskiene i forhold til de med 2er hjul?

□ Vesentlig treigere (>5%) □ Litt treigere (2-5%) □ Ingen forskjell □ Litt raskere (2-5%) □ Vesentlig raskere (>5%)

Test 3: Hvordan opplevde du rulleskiene i forhold til de med 2er hjul?

□ Vesentlig treigere (>5%) □ Litt treigere (2-5%) □ Ingen forskjell □ Litt raskere (2-5%) □ Vesentlig raskere (>5%)

Takk for deltagelsen :)

3.7 Attachment 2:

Til trenere for Wang toppidrett Oslo utholdenhet (langrenn, skiskyting, sykling og orientering)

Fra: Bojan Blumenstein, Frank Eirik Abrahamsen, Thomas Johansen Losnegard, Norges Idrettshøgskole (NIH).

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Vi takker på forhånd for samarbeidet, og ser fram til møtet med dere i forbindelse med undersøkelsen.

Sportslig hilsen,

Bojan Blumenstein, Frank Eirik Abrahamsen, Thomas Losnegard, Norges Idrettshøgskole.

4. Article

Placebo and Nocebo in Sports: Potential Effects of Hypothetical Differences in Roll Resistance on Roller Ski Performance

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Norwegian School of Sport Science

4.1 Abstract

Although the placebo and nocebo effects of ergogenic aids are acknowledged as a significant factor for sports performance, little is known about the effects of different sports equipment. Therefore, we examined how athletes' belief about their sports equipment affected skiing performance in a short time trial, together with their subjective rating of performance.

In a randomized controlled trial with crossover design, 21 junior cross-country skiers completed a repeated straight 45 m indoor double poling protocol. All trials were performed on roller skis with the same roll resistance. For the baseline trial, the skis were marked with "medium roll resistance". For the experimental trials, the athletes were randomized into two groups and were given a set of new roller skis, marked as "low roll resistance" (placebo), and "high roll resistance" (nocebo). The time for each individual trial was measured with photocells, while post-experimental questionnaires examined the skiers subjective rating of the performance.

The mean speed was the same for the placebo and baseline trials. However, the mean speed for the nocebo trial was slower compared to the baseline trial (mean±95 CI; -0.7%±0.4%, *P<0.002)*. The subjective experience of the roller skis used during the experimental trials was different to that of the baseline trial (placebo: P<0.001; nocebo: P<0.002).

Our findings reveal that athletes' negative belief of their sports equipment influenced performance negatively. In sports such as cross-country skiing, where equipment is vital, it is advised that the negative psychological effects should be mitigated by downplaying the importance of equipment on overall performance.

Keywords: belief effects, motivation, cross-country skiing, roller-skiing, performance psychology, physical performance, fluorinated skiing wax, sports equipment

4.2 Introduction

Nearly four decades ago, a study revealed that a placebo injection could be as effective as 6–8 mg of morphine for relieving pain [1]. Since then, most studies conducted in the field of medicine using placebos have confirmed the existence of both placebo and nocebo effects [2]. Furthermore, individual differences exist, where some individuals can be classified as more likely placebo responders than others [3].

Over the last two decades, in addition to qualitative research and anecdotes from elite athletes [4], more than 30 studies with experimental designs have focused on placebo and nocebo effects on sport performance. However, while most of these studies involved placebo effects of ergogenic aids, studies focusing on the placebo and nocebo effects of sports equipment are lacking [5]. In sports such as cross-country skiing, the waxing, structure, and quality of the skis has a substantial impact on performance [6]. However, to date little is known about how athletes' beliefs about the quality of their skis as a decisive factor on performance influence performance.

Fluorinated waxes have been used to reduce ski-snow friction in cross-country skiing for decades. From July 2020, the production of these fluorinated waxes will be forbidden by EU-law [7] due to their negative impact on the environment [8, 9] and human health [10, 11]. From the winter season 2020/21, fluorinated waxes will be banned in a gradual manner by the FIS in all skiing sports [12, 13]. Because fluorinated skiing waxes are costly compared to normal waxes [9], this implies a major advantage for the affluent classes in society and further leads to reduced motivation or enjoyment for athletes with less monetary means [14].

Given the potential advantages gained from using fluorinated skiing waxes, it is also of interest to understand whether athletes' beliefs about their equipment indirectly affect performance. If a change in belief could have an impact on athletes' performance (or the subjective experience of their performance), their mastery experience may also change. Thus, a significant change in the mastery experience might have an impact on general motivation for sports participation [15].

To the best of the authors' knowledge, the only experimental study conducted that considered the impact of the sports equipment itself concerned tennis rackets. The study

showed that a modified tennis racket (whether real or placebo) could improve the player's mean tennis serve performance by 5.6% [16]. Since this study only included placebo effects, the question remains unclear whether having worse equipment than your opponent might produce a negative placebo effect ("nocebo effect"), and therefore be harmful to the athletes' performance and motivation.

The present study was designed to examine whether hypothetical differences in the quality of cross-country skis can trigger a placebo and/or nocebo effect in junior cross-country skiers. To increase the measurement reliability, we used roller skis on an indoor hall surface instead of cross-country skis on snow (see Limitations and further research). Furthermore, we were interested to investigate whether a false belief about the rolling resistance of the roller skis could affect the athlete's subjective experience of the equipment. More specifically, the present study used a randomized controlled trial with cross-over design and post-experimental questionnaires to test three hypotheses: First, subjects executing the task with the placebo intervention will perform better when compared to the baseline trial. Second, subjects executing the task with the nocebo intervention will perform worse compared to the baseline trial. Third, the subjects' false belief about their equipment will change their subjective judgment about their performance after the trial.

4.3 Method

4.3.1 Ethical considerations

The study followed the ethical guidelines of our institution and had full approval of the ethics committee of the Norwegian School of Sport Science. The participants in this study gave their informed consent to take part in this study. The experimental protocol was similar to speed training that the athletes are accustomed to as part of their weekly training. After the study, the participants were debriefed about the true purpose of the study and allowed to ask questions.

4.3.2 Subjects

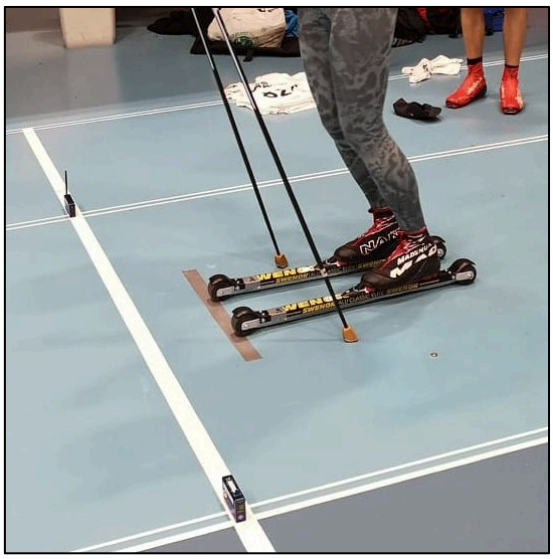
The sample included 21 junior athletes (15 male and 6 females; mean ± SD; 17.1 ± 0.9 years) from sports including cross-country skiing and biathlon. The subjects were all students at a Norwegian sports school and were engaged in regular training (daily), all performing at a high national level. The subjects were randomly assigned to two groups,

although we checked that there was no group difference according to gender, age, or main sport.

4.3.3 Materials

Roller skis: The experiment was executed in an indoor hall on standardized roller skis used for classic-style skiing (Swenor Classic Elite; wheel type 3). The roller skis were from the same production series. After testing 10 pairs of roller skis in a standardized friction test on a treadmill [17], we were able to establish the 2 pairs of roller skis that deviated the most from the mean rolling resistance. The remaining 8 pairs of roller skis used for the experiment demonstrated no significant difference in rolling resistance. Two pairs of roller skis were used for the placebo condition, four were used for the baseline condition and two were used for the nocebo condition. Statistical post-experimental analysis revealed that the measured rolling resistance of the roller skis used during the trials had no significant correlation with the time the subjects used during the trial ($R = -0.033$). For this reason, the effect of the measured rolling resistance on performance was considered non-existent and was therefore not included in further analysis. Even if the rolling resistance was the same for every pair of roller skis used for the experiment, the numbers on top of the roller skis that indicated a hypothetical rolling resistance (1 = low (placebo), 2 = medium (baseline) and 3 = high (nocebo)) were visible to the subjects.

Poles: Cross country skiing poles (SWIX Triac 2.0) with a custom-made rubber cap for indoor use were distributed to the subjects appropriate to their height (~84% of body height).



Picture 1: *Standardized starting position*

Shoes: Subjects used their own skiing shoes (classic style).

Warming locker: Roller skis not in use during the running trial were kept in a warming locker (Swix, Warmbox T007680- 110, Lillehammer, Norway). The warming locker maintained a steady temperature of 60 °C to keep the rolls at the same temperature. This was to avoid a change in rolling resistance that can occur between cold and warm rolls [18].

Start position: The starting position was standardized with tape markers on the ground 20 cm before the starting laser cell, as shown in Picture 1.

Time keeping: Time was recorded to the nearest 0.01 s by timekeeping laser cells (Portable Brower Speed Trap II, Brower Timing Systems, Utah, USA).

Questionnaire: Questionnaires were designed to investigate whether the roller skis used in the previous trial felt different in speed compared to the roller skis from the baseline trial. In the questionnaire, the subjects could tick off one out of five possible answers. An extract of the questionnaire is shown in Table 1.

	How did you experience the speed of the roller-skis compared to Trial 2?				
Trial 3	□Much slower >5%	□A bit slower 2-5%	□No difference	□A bit faster 2-5%	□Much faster >5%
Trial 4	□Much slower >5%	□A bit slower 2-5%	□No difference	□A bit faster 2-5%	□Much faster >5%

Table 1: *Questionnaire to investigate the subjective experience of speed.*

4.3.4 Procedure

The test protocol for the experiment, presented in Table 2, indicates the order in which the study was completed.

All subjects started with a 20 min warm-up that was designed to warm up the specific muscle groups used in cross-country skiing. Then, subjects met with the testing staff for a short briefing session about the study. During the briefing session, subjects were

introduced to a “cover story” to avoid revealing the true purpose of the study: The subjects were told that they were going to perform a 4 × 45 m indoor roller ski sprint protocol with different types of roller skis to test some new roller ski material from SWENOR. For this purpose, subjects were told that the difference between the roller skis was their rolling resistances (low, medium, and high). Accordingly, the difference in rolling resistance (according to the producer and marketing experts in the field of roller skis [19]) was stated as being 4%–6% between each of the categories (even though it actually was the same for each roller ski). The subjects were encouraged to perform an all-out sprint for each trial, regardless of which type of roller ski they were using. To complete the test successfully, only double poling technique was allowed and the finish line was supposed to be crossed with both feet on the same length.

For subject to become accustomed to the equipment and the task, a test trial (trial 1) on roller skis marked with number “2” (hypothetical medium rolling resistance) was executed by every subject. No time was recorded for the test trial.

After a break of ~4 min, groups 1 and 2 started with the baseline trial (trial 2) on roller skis marked with number “2” (hypothetical medium rolling resistance).

The third and fourth sprint (trials 3 and 4) were performed on roller skis with hypothetically low rolling resistance (roller skis marked with the number “1” – placebo) followed by high rolling resistance (roller skis marked with the number “3” – nocebo) for Group 1, and the other way around for Group 2. Between each trial, the subjects had a 4 min break.

After both experimental trials (trial 3 and trial 4), the subjects completed the questionnaire about their subjective experience using the different type of roller skis (see Materials section). After all subjects had performed all sprints and filled out the questionnaire, they were taken for a short debriefing session, where the true nature of the study was revealed (see Ethical Considerations).

Table 2: *Test protocol.*

	Group 1	Group 2
Trial 1	Warm up, briefing session and test trial	
Trial 2	Baseline (roll 2)	Baseline (roll 2)
Trial 3	Placebo (roll 1)	Nocebo (roll 3)
	Questionnaire	
Trial 4	Nocebo (roll 3)	Placebo (roll 1)
	Questionnaire	
	Debriefing session	

4.3.5 Statistical analyses

All descriptive data are presented as mean ± SD. Data representing relative differences are presented as mean ± 95% confidence interval (CI). One-way ANOVA analyses were used to detect statistical differences between baseline, placebo, and nocebo groups. Bonferroni post hoc analyses (multiple comparisons) were used to compare the time used for the trials depending on the answers given in the post-trial questionnaires. Paired t-tests were used to investigate differences in the subjective experience of speed between the experimental trial and the baseline trial. A P-value of < 0.05 was considered statistically significant. All analyses were conducted using Microsoft Excel and SPSS software.

4.4 Results

45 m time-trial: The mean time result for the 45 m trial was 8.19 ± 0.61 s for the baseline condition, 8.18 ± 0.58 s for the placebo condition, and 8.25 ± 0.60 s for the nocebo condition. This corresponds to a significant difference in speed for the nocebo condition compared to the baseline condition (-0.7% ± 0.4%, *P < 0.002), and for the nocebo condition compared to the placebo condition (-0.8%* ± 0.4*%, P < 0.001)*. No significant difference in speed was found for the placebo condition compared to the baseline (0.1% ± 0.5%, P = 0.58) (Figure 1).

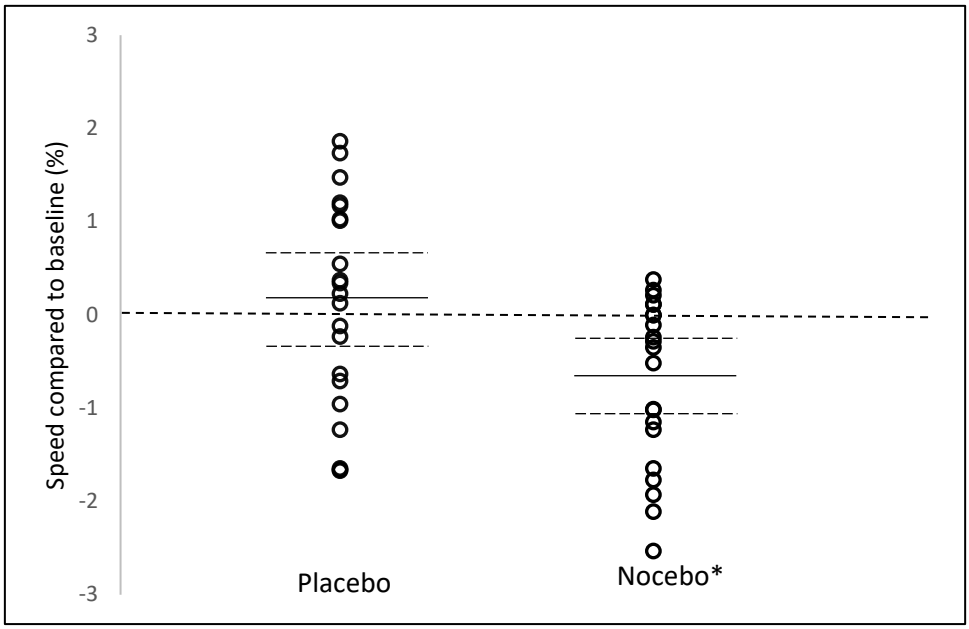


Figure 1: *Individual differences in speed between experimental trial (placebo and nocebo) and baseline trial. Horizontal full lines indicate the relative mean differences in %, and horizontal dashed lines, upper and lower 95% CI (N = 21). *=significant different (P < 0.002) to baseline (0).*

Questionnaires: Of the 21 subjects, 20 reported that either the placebo roller skis went faster (n=10), the nocebo roller skis went slower (n=4), both the placebo roller skis went faster and the nocebo roller skis went slower (n=5), or that both the placebo and the nocebo roller skis went faster (n=1). One subject reported that there was no difference in speed for any of the roller skis used during the trials. It was reported by 16 out of 21 subjects (76%) that the roller skis went faster during the placebo trial compared to the baseline trial. For the nocebo trial, 9 out of 21 subjects (43%) reported that the respective roller skis went slower compared to the baseline trial (Figure 2).

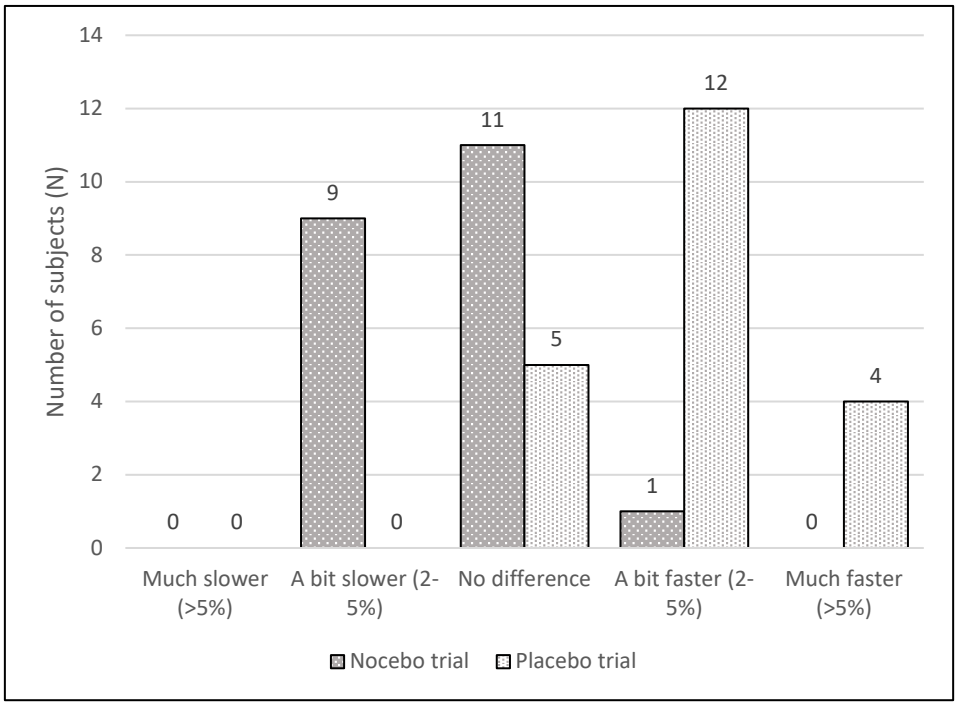


Figure 2: *Distribution of answers from the post-trial questionnaires for placebo condition (N = 21) and nocebo condition (N = 21).*

The mean distribution of the answers shows that the subjects felt a significant difference from the placebo to the baseline trial ($P < 0.001$) and from the nocebo to the baseline trial ($P < 0.002$) (Figure 3).

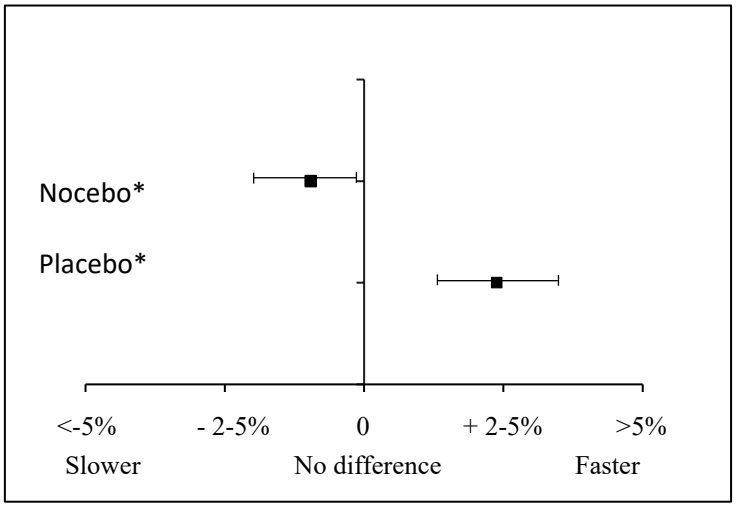


Figure 3: *Subjective experience of roller ski speed in placebo and nocebo trials (mean ± 95 CI). *= significant different (P < 0.002) to baseline (0).*

45 m time trial grouped after questionnaire answers: We divided the trials into groups regarding subjective experience of speed compared to the baseline trial. The average difference in speed (for placebo and nocebo) compared to the baseline trial, when divided into the corresponding groups, shows no significant difference in speed. The only statistical mean difference in speed compared to the baseline trial is seen for the nocebo group as a whole (Figure 1) regardless of answers provided on questionnaires.

Dividing the trials into bigger groups (any difference and no difference) does not show any further significant differences. In other words, the mean time difference for the placebo trial compared to the baseline trial does not differ significantly between those subjects who felt that the roller skis where going faster and those who felt that there was no difference compared to the baseline trial ($P = 0.70$). For the nocebo trial, the mean time difference compared with the baseline trial does not differ significantly between the subjects that felt that the roller skis were going any slower and those that felt that there was no difference (or a bit faster) ($P = 0.13$).

4.5 Discussion

This study investigated whether a change in belief among young cross-country skiing athletes about their sports equipment (roller skis) could impact their sporting performance (45 m sprint on roller skis), together with their subjective judgment about the performance.

Our main findings were as follows:

- Subjects that executed the task with the placebo intervention performed no differently compared to the baseline trial.
- Subjects that executed the task with the nocebo intervention performed worse compared to the baseline trial.
- Subjects' false beliefs about their equipment changed their subjective judgment about their performance after both the placebo trial and nocebo trial).

We found a significant nocebo effect and a significant difference in time between the placebo and the nocebo conditions. Although a difference in time of -0.8% (between

placebo and nocebo-trial) seems small, it is likely to influence sports performance in cross-country skiing, because the smallest worthwhile enhancement in performance for the world's top 10 skiers is ~0.4% [20]. If we transfer our results into a typical distance event with a duration of 30 min, a hypothetical difference for elite athletes would be approximately 14 s, even if every competitor used exactly the same pair of skis. Here, we can infer that 12 s of difference would occur because the athletes believe that they have worse equipment than their opponents (negative belief – nocebo) and would therefore perform worse than their usual average. However, placebo and nocebo effects are influenced by numerous external factors, such as the appearance of the sports equipment itself (e.g. color, condition, price), the environment (e.g. inside a hall, outside on snow, with or without spectators), or the interference of researchers and other participants (e.g. attitudes, behavior, communication) [2]. Furthermore, only junior athletes were tested in the present study, and a 45 m indoor sprint protocol on roller skis with very few spectators engenders a different psychological state for the athlete (e.g. another level of stress) and is less physically demanding than a "real" 30 min distance race on cross-country skis. Therefore, these calculations should be considered advisedly. However, former studies show that performance became progressively faster when the experimental design tested athletes more on endurance in the placebo trials (e.g. multiple repeated trials with short breaks) and progressively slower in the nocebo trials [4]. We can therefore assume that the relative difference in time between athletes with positive belief and athletes with negative belief is relevant for performance and might be even bigger for a duration of greater than 45 m sprint such as that used in this study.

There was no significant enhancement in mean speed from the baseline condition to the placebo condition (0.1%), which is in contrast to Aymeric et al. (2012) who found a 5.6% enhancement of serve accuracy in tennis with a modified tennis placebo racket [16]. However, the fact that we found a significant nocebo effect, while there was no significant placebo effect in sprint performance, is in line with former studies on ergogenic aids [21, 22]. This implies that the direction of placebo and nocebo effects of ergogenic aids in sprint performance can be applied to the effects of hypothetical differences in rolling resistance in sprint performance. Furthermore, studies from other sport disciplines such as weightlifting or cycling show that placebo effects resulting from nutrition (e.g. caffeine, amino acids, carbohydrate) are similar to those resulting

from mechanical interventions, such as modified tennis rackets, kinesiology tape, or magnetic wristbands. However, banned substances such as anabolic steroids demonstrated a significantly larger placebo effect than legal substances or mechanical interventions [5]. We can therefore infer that the placebo and nocebo effects of skis prepared with fluorinated skiing waxes may be even bigger from the winter season 2020/21 when fluorinated skiing waxes will be banned.

It is also documented that the price of an object alone can trigger placebo and nocebo effects [23]. The roller skis used in this study where introduced to the subjects only as different in rolling resistance (not in price). However, fluorinated skiing waxes are much more expensive than usual skiing waxes [9] and might therefore influence placebo and nocebo effects in a different way under real life skiing conditions (such as in competition) than the roller skis did in this study.

In this study, the post experimental questionnaires clearly showed that the placebo roller ski was evaluated as being faster ($P < 0.001$) and the nocebo roller ski was evaluated as slower ($P < 0.002$). Looking at the differences in speed in the trials (placebo and nocebo) compared to the subjective experience of speed provides some answers as to why 20 out of 21 subjects felt that their roller skis where different in speed, even if they had the same rolling resistance. The fact that there was no difference in speed in the trials (for both placebo and nocebo) between those who felt a difference in the speed and those who could not feel a difference shows that the subjective experience in speed is a result of the false belief of the subjects before the trial, rather than the speed they actually achieved during the trial. Giving athletes a certain belief about their equipment will modify their anticipation about the outcome of the performance. Athletes with a positive belief about their equipment will anticipate a better outcome compared to athletes that have a negative belief. Our results indicate that this difference in anticipation as a result of false belief will influence the performance regardless how the athlete experienced the performance in retrospect. These results confirm that the subjects' expectancy plays a main role when it comes to the mechanisms of placebo and nocebo effects [2] and that placebo and nocebo effects can influence performance, even if the subject does not feel a difference compared to the baseline [24].

Since the athletes' negative belief about their equipment has a direct negative impact on performance but a positive belief has no positive impact on performance, the mean performance of all athletes will decline (assuming that there are as many positive believe athletes as there are negative believe athletes). Even if positive and negative experiences about the differences in ski equipment compensate for each other in retrospect, the negative impact on performance would still affect result lists in real-life skiing competitions and lead to a loss in mastery experience for some athletes. With repeated poor mastery experiences, an athlete's self-efficacy can diminish and the nocebo effects would therefore have a negative impact on their enjoyment and overall motivation for sports participation [15].

4.6 Limitations and further research

A potential weakness of the study is using roller skis in an indoor hall, which is not fully comparable to usual competition conditions experienced by athletes in outdoor cross-country skiing races. This might have a negative effect on the extern validity. However, we decided to conduct the experiment with only short double polling sprints in an indoor hall on standardized roller skis to increase the measurement reliability (the coefficient of variation for a 30 m double polling sprint is 0.9% (unpublished from our lab). In addition, we could control extraneous external factors such as weather conditions or differences in skiing equipment (such as the span, the grinding of the sole, or remaining wax from previous use). Finally, the study only included junior athletes. It therefore remains unclear how the results can be applied to senior elite athletes.

To increase external validity, it would be interesting to establish whether and how the placebo and nocebo effects change when the athletes are aware that their skis are prepared with expensive and soon-to-be banned substance like fluorinated skiing waxes. To draw conclusions about the cause of the partly-false subjective experiences of speed it is necessary to conduct experimental studies with a larger sample size, longer or repeated trials focusing on endurance, and more specific post-experimental questionnaires that focus more on the cause of differences in speed and subjective experience. Longer trials would also give a more realistic picture of the size and direction of placebo and nocebo effects, since they would more closely relate to "real-life" competitions. Post experimental interviews and more qualitative research on active

cross-country skiing athletes should be considered to determine how placebo and nocebo effects change the athletes' motivation and self-efficacy.

4.7 Perspective

With the nocebo effect being significantly stronger than the placebo effect when it comes to the use of different sports equipment, it can be assumed that equipment-based sports such as cross-country skiing are facing a challenge when there is too much focus on the equipment as a decisive factor on performance. To create a motivational climate in youth sports and ensure high numbers in sports participation, nocebo effects should be avoided where possible. Coaches should reinforce the focus on learning processes, overall sports enjoyment, and downplay the importance of equipment as a decisive factor on performance. Such a behavior would also contribute to a broad number of participants from all classes of society including athletes with less monetary means. Next to the avoidance of an overall reinforcement of focus on sports equipment, it should be considered to avoid significant differences in the quality of sports equipment between athletes during competition. Athletes could for example use standardized material provided by the organizers, or more specific from the sport of cross-country skiing, deliver their skis to the organizer for getting a standardized non-flour waxing preparation.

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