



# Tyre-pulling as concurrent training

Asgeir Mamen<sup>1</sup> · Per Morten Fredriksen<sup>1</sup>

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## Abstract

**Background** Concurrent training has gained popularity as a health-promoting activity. The focus of this study was to investigate the feasibility of tyre-pulling as a strength and endurance training exercise.

**Methods** Thirty-four volunteered participants accepted to comply with an 8-week training program, and were by drawing lots divided into three groups: long-distance training, high-intensity interval training and control groups. The long-distance group exercised 60 min at 75–85% of HR<sub>max</sub> three times a week. The high-intensity interval group also exercised three times a week with 10 intervals of 20 s and a rest of 10 s in an all-out intensity. The control group continued their ordinary activities. A test battery, measuring arm and leg strength, core strength, and endurance, were taken at the beginning and after 8 weeks. Anthropometric measurements and spirometry test were performed likewise.

**Results** The high-intensity group had increased maximal oxygen uptake by 2.6 (2.2) mL kg<sup>-1</sup> min<sup>-1</sup>. The number of repetitions in arm strength increased with 4.2 (3.5), for leg strength, the increase was 7.9 (9.2) repetitions. Leg strength increased in the long-distance group with 13.6 (14.7) repetitions and core strength increased with 30.3 (34.0),  $p \leq 0.05$ . No significant changes were observed in the control group.

**Conclusions** Tyre-pulling is feasible for training endurance and strength at both low and high intensities.

**Keywords** Fitness · Strength training · Endurance training · Whole body training

## Introduction

Concurrent training is training both strength and endurance at the same time. “Circuit Training” was developed by Ronald Ernest Morgan and Graham Thomas Adamson from the University of Leeds in 1953. Nine to 12 stations with a work period of 15–45 and 15–30 s rest periods were the original set up, where the subjects used 40–60% of 1RM when training. This training form has recently gained new popularity. The concept has been marketed as “cross-training”, “cross-fitness”, and “metabolic resistance training”. The CrossFit™ brand was created in 2000 by Greg Glassman and Lauren Jenal, and reported over 13,000 gyms worldwide. Concurrent training has been found to be inefficient in some studies, as the endurance training interferes with the hypertrophy

development [1, 2]. Others have found it useful [3, 4]. Baar [5] recommends both nutritional strategies and temporal adjustments to the training scheme to make a successful concurrent training. Nordic walking (NW) and tyre-pulling can be considered as concurrent training because they involve both endurance and strength training. The effect of NW has been investigated both in the field and in laboratory conditions, while tyre-pulling is still a less investigated concept [6–8].

Already in the 1930s, cross-country skiers detached the top of a Norway spruce tree (*Picea abies*) and dragged it during the training sessions to increase the workload of the arms. A similar technique was also used during the summer training activities [9]. Also, power athletes, speed skaters and sprinters may use a similar concept of pulling resistance, using parachute, car tyres or a training partner to increase the load. The theory is that dragging a heavy load sharply increases the energy expenditure and helps gaining strength and endurance [10–13].

According to Timothy David Noakes, the largest energy expenditure that is endured by humans was done by Robert Scott and his men on their South Pole expedition [14].

✉ Asgeir Mamen  
asgeir.mamen@kristiania.no

Per Morten Fredriksen  
permorten.fredriksen@kristiania.no

<sup>1</sup> Department of Health Sciences, Kristiania University College, Prinsensgate 7-9, 0152 Oslo, Norway

The team managed to man-haul their sledges for 159 days, using a total of 1 million kilocalories (kcal)/42,000 mega joule (MJ) per person [more than 6000 kcal (25 MJ) pr. day]. This is about the same daily energy expenditure that Tour de France cyclists use [6000–8000 kcal (25–33 MJ), for 21 days] [15]. Therefore, tyre-pulling has also become a regular training activity for the preparation of self-sustained expeditions to polar regions, as these expeditions require an unavoidable and huge level of sledge pulling [16].

Since dragging an object has provided benefits for cross-country skiers, it has become more common for Norwegian cross-fit coaches to include tyre-pulling as a total body workout.

A large amount of literature is available regarding training benefits on health using endurance exercises like walking, running and NW. Traditional endurance training can be done at different intensities and durations; therefore, it is often divided into low-intensity training with long duration, lactate threshold training with medium duration and high-intensity interval training with short duration [17]. There is small availability of research comparing the efficacy of different intensity modes using tyre-pulling. Thus, the aim of this study was to investigate the development of endurance and strength with tyre-pulling at low and high intensities.

## Methods

### Participants

The participants volunteered from a local University College and consisted of students of both sexes between 20 and 50 years. They were all physically fit, active and able to perform a minimum of 1–2 h of strength or endurance exercises at least three times a week.

Participants with any form of chronic illness which hindered their ability to complete the training were excluded. Besides, participants who did not accomplish at least 75% of the training sessions, indulged in smoking, who experienced unexpected values in resting blood pressure, any experience of chest pain and any other cardiovascular events during training were not eligible.

### Ethical considerations

Each participant was informed orally and in writing about the purpose of the study before giving informed, written consent. It was specifically pointed out to the participants that they were acting as volunteers and also that they could leave the study at any stage without giving a reason. In Norway, such studies do not need specific approval by a national ethics committee.

**Table 1** Age distribution of the participants in three different study groups

	<i>n</i>	<i>n</i> females (%)	Age (SD)
Total	34	21 (62%)	23.1 (5.0)
CG	12	6 (50%)	25.3 (7.7)
HIIT	13	9 (69%)	21.9 (2.1)
LD	9	6 (67%)	22.2 (1.6)

### Grouping criteria

The participants were then randomly divided into control group (CG), long-distance training group (LD) and high-intensity interval training group (HIIT), by drawing lots. After randomization, three participants declined to proceed further, four became ill during the training period and 10 participants had completed less than 75% of the training sessions. Overall, 34 participants, 19–49 years, 60% females, completed the training and two tests (Table 1).

### Anthropometric measurements

A Seca 875 scale was used to measure body mass and for stature we used a Seca 217 stadiometer (SECA GmbH, Germany). Waist circumference was measured using a conventional measuring tape at umbilicus level after a normal expiration, according to WHO procedures [18]. The anthropometric measurements were recorded at the beginning and after completion of the training period.

### Cardiopulmonary fitness

The health status of the participants was evaluated at both pre- and post-intervention by conducting a medical exam which included spirometry, resting heart rate (Schiller Cardiovit AT-104, Schiller AG, Baar, Switzerland) and resting blood pressure (Schiller BT-200+, Schiller AG, Baar, Switzerland). The measurements for resting heart rate and blood pressure were taken after 5 min of supine rest. All testing took place in the morning/noon and the subjects were instructed to not train hard the day before, and not to eat the last 3 h before testing. Other than this, there was no control of diet or restrictions on what to eat.

### Lactate threshold and $O_{2peak}$

A Lactate Pro LT-1710 analyser (Arkay Inc., Kyoto, Japan) was used to measure blood lactate concentration. This portable, credit card size, analyser has been investigated by several researches and found valid for a wide range of conditions [19, 20]. The protocol consisted of 5 min steps on

treadmill (Woodway PPS55, Woodway GmbH, Weil am Rhine, Germany). Starting speed was set individually, and varied from 1.67 to 2.22 m s<sup>-1</sup>. It was the same for both pre- and post-test. The inclination was 1.5% and the increase in speed was 0.42 m s<sup>-1</sup> for each step throughout the test. The lactate threshold was defined as the blood lactate concentration exceeded the resting value with 2 mmol L<sup>-1</sup>. This has been shown to correspond to the Maximal Lactate Steady State load when using this analyser [21]. After at least 5 min of active recovery following the lactate profile test, a maximal oxygen uptake test was conducted.

During the maximal oxygen test, the inclination was raised to 5.3% and speed was increased every minute at a rate of 0.28 from 1.67 m s<sup>-1</sup> until the participant reached volitional exhaustion. A Moxus 3rd generation metabolic cart (AEI Technologies, PN, USA) continuously sampled expiration gases with the participant breathing through a Hans Rudolph 2700 two-way non-rebreathing valve fitted on a Hans Rudolph V2700 oronasal facemask (Hans Rudolph, Inc., Kansas City, USA). Also, the heart rate was recorded continuously with a Polar Heart Rate Monitor (Polar Electro Oy, Kemple, Finland).

## Strength tests

There are few standardised tests that involve endurance test of shoulder extension. The “Bråsterk”<sup>1</sup> Test was used to test the strength of extensor muscles in the shoulder. “Bråsterk” is extensively used in the training program for cross-country skiers for double pooling ability. “Bråsterk” has a set of rails where a sledge rolls. The body is placed on the sledge stomach down, arms stretched and hands grip the pulling ropes. The workload may be changed by increasing or decreasing the slope of the rails, and/or adding weight on the sledge. The starting point (bottom position) is at full stretch in shoulder and elbows, while the ending point (top position) is when the elbows are fully stretched and parallel to the upper body. The number of times the participants reached the top of the rails was recorded, and the test was terminated when the participants were unable to stretch their elbows at the end-point on top of the rail. The female participants used a lower incline than the male participants, without extra weight on the sledge, and the men used an extra 10% of their body mass on the sledge.

A Core Stability Test was used to determine whether tyre-pulling influences the core muscles in the trunk. A modification of the test was used to limit the time to exhaustion,

as some participants could stay in the original abdominal plank exercise position for 10–15 min. To establish the testing positions, the participants slid backwards from a push-up position until they no longer could hold the position. A supervisor then measured the distance between the start and end position of their feet with a measuring tape. The actual test position of the feet was the end position minus 20% of the distance taken. The time held in this position was measured in seconds.

The Bulgarian Split Squat [22] with additional weight on the shoulders was used for measuring the endurance strength of leg muscles. The front knee should start a full stretch and bend to 90° angle, the hind foot should stay on the ground and the knee should touch the floor at each bend. McCurdy et al. [22] proposed that in this position, 85% of the weight bearing is on the front leg. The test load was found by adding 40% of the body mass for the female participants and 50% for the male participants. The test was terminated if the participants lost their balance or were unable to reach the floor with their hind knee. The Bulgarian Split Squat test has been proven to have a high reliability [22].

## Training procedures

### Walking poles and pulling tyres

The participant’s body height was multiplied with 0.70 to find the correct length of the walking poles. The size of tyre or the number of tyres was tested at the first training session. Each individual found a suitable load, according to the mode of training. During training, the tyre was connected to the participants via an elastic cord attached to a hands-free dog leash (Kennel, Germany), connected to the waist of the participant.

### Training

The LD group trained together under supervision for 60 min, three times a week for 8 weeks, pulling tyres and using walking poles in the terrain or along dirt roads. The person uses normal diagonal technique and pulls the tyre(s) using arms and leg force. After 5 min of warming up, the training intensity was kept at 70–85% of HR<sub>max</sub> monitored by a Polar Team 2 heart rate system (Polar Electro Oy, Kemple, Finland). Totally, the participants performed 24 h of training across 2 months, and a 75% attendance was required for inclusion in the analysis.

The HIIT group also trained three times a week under supervision, with a 10-min warm up. The work intervals were 20 s with 10 s rest repeated 10 times, giving 3 1/3 min of exercise with an all-out intensity, monitored with Polar Team 2. This training was done with the highest intensity for 20 s, and on a smooth asphalt surface.

<sup>1</sup> The word “Bråsterk” literally means “quickly strong”. The product was introduced to the Norwegian market in the 1980s with the aid of world cross-country ski champion Oddvar Brå, hence the double meaning of the name.

**Table 2** Pre- and post-intervention results for the three groups in means and SD

	CG <i>n</i> = 12		HIIT <i>n</i> = 13		LD <i>n</i> = 9	
	Pre	Post	Pre	Post	Pre	Post
BM (kg)	68.5 (8.1)	69.2 (7.8)	66.8 (10.4)	66.7 (9.3)	69.3 (8.8)	69.3 (8.1)
WC (cm)	78.8 (5.7)	79.1 (5.8)	77.5 (6.9)	77.1 (6.2)	78.9 (5.9)	79.6 (4.8)
HC (cm)	85.5 (3.6)	85.3 (3.6)	84.8 (5.3)	84.0 (4.0)	85.8 (3.3)	85.4 (4.5)
BP <sub>Sys</sub> (mmHg)	132.1 (12.6)	131.9 (14.3)	138.8 (16.4)	<b>128.5 (10.9)</b>	138.6 (12.1)	<b>125.9 (9.0)</b>
BP <sub>Dia</sub> (mmHg)	73.0 (6.5)	73.6 (6.6)	76.3 (7.8)	72.5 (7.8)	73.1 (7.7)	69.6 (8.6)
HR <sub>rest</sub> (BPM)	69.1 (13.5)	68.5 (13.5)	73.2 (9.9)	75.0 (13.1)	76.7 (10.9)	<b>64.6 (13.5)</b>
HR <sub>lt</sub> (BPM)	176 (12)	176 (12)	177 (8)	174 (8)	175 (13)	173 (12)
HR <sub>max</sub> (BPM)	199 (9)	198 (8)	197(8)	195 (7)	194 (6)	193 (8)
FVC (L)	5.1 (1.0)	5.1 (1.0)	4.7 (0.8)	4.6 (0.9)	4.9 (0.9)	4.9 (0.7)
FEV <sub>1</sub> (L)	4.2 (0.9)	4.2 (0.9)	4.0 (0.6)	4.1 (0.7)	4.2 (0.8)	4.0 (0.6)
Arm (reps)	16.3 (6.0)	17.1 (6.0)	16.2 (6.4)	<b>20.3 (7.7)</b>	17.9 (5.8)	19.4 (6.8)
Leg (reps)	38.7 (21.1)	38.9 (21.5)	33.7 (10.0)	<b>41.6 (15.7)</b>	35.3 (11.0)	<b>47.9 (23.8)</b>
Core (s)	132.3 (55.0)	134.0 (55.5)	190.5 (119.8)	202.6 (119.1)	127.9 (67.1)	<b>156.8 (70.2)</b>
VO <sub>2peak</sub> (mL kg <sup>-1</sup> min <sup>-1</sup> )	49.4 (6.2)	49.3 (5.4)	47.8 (4.1)	<b>50.4 (4.7)</b>	48.7 (6.1)	49.1 (6.1)
VO <sub>2lt</sub> (mL kg <sup>-1</sup> min <sup>-1</sup> )	37.8 (6.8)	38.4 (5.2)	38.1 (4.3)	40.0 (5.4)	38.7 (4.1)	38.9 (3.7)
aVO <sub>2peak</sub> (L min <sup>-1</sup> )	3.39 (0.60)	3.46 (0.58)	3.21 (0.66)	<b>3.39 (0.72)</b>	3.38 (0.67)	3.43 (0.75)
TTE (s)	473 (78)	453 (80)	437 (69)	470 (73)	469 (75)	488 (71)
v <sub>lt</sub> (m s <sup>-1</sup> )	2.63 (0.42)	2.63 (0.34)	2.70 (0.42)	2.82 (0.34)	2.75 (0.33)	2.85 (0.28)

Numbers in bold marks significant difference between pre- and post-test ( $p < 0.05$ )

CG control group, HIIT high-intensity interval training group, LD long-distance training group, BM body mass, WC waist circumference, HC hip circumference, BP blood pressure, HR heart rate, FVC forced vital capacity, FEV<sub>1</sub> forced expiratory volume in 1 s, Arm arm strength (Bråsterk), Leg leg strength (Bulgarian split), Core plank, VO<sub>2max</sub> maximal oxygen uptake, TTE time to exhaustion, lt lactate threshold

Also, here the arms and legs were important for producing the necessary force, using classic diagonal technique. A total of 1 1/3 h of HIIT training, divided into 24 sessions across 2 months. Again, 75% attendance was required. Training was conducted from end of August to mid October. The CG continued with their regular training habits.

## Statistics

Data were checked for normality with Shapiro–Wilk test. Paired *t*-test or, in the few cases that normality test failed, Wilcoxon signed-rank test were used to analyze changes at pre- and post-tests. Two-way ANOVA, with group and sex as factors was used to analyze differences between groups. With the help of a web calculator, Cohen's effect size (*d*), was calculated (<https://www.cem.org/effect-size-calculator>). The results are presented as mean and standard deviation (SD) unless otherwise stated. A  $p$  value  $\leq 0.05$  was taken as a significant difference. We used SigmaPlot v.13 (Systat Software GmbH, Erkrath, Germany), Systat v.13 (Systat Software Inc., San Jose, CA, USA) and Winks SDA Pro 7.0.9 (TexaSoft, Cedar Hill, TX, USA) statistical software.

## Results

The training programs led to significant differences between pre- and post-testing on several variables between training groups. There were no differences between males and females or interactions between training group and sex in development between the two test times. The HIIT group increased their aerobic power, arm strength (“Bråsterk”) and leg strength (Bulgarian split) (see Table 2). Systolic blood pressure was reduced significantly. The LD group significantly increased their leg strength and core strength (stability). A significant reduction in systolic blood pressure was found. The CG showed no significant changes.

## Aerobic fitness

The HIIT group increased their oxygen uptake 6% and was the only group with a significant ( $p < 0.01$ ) improvement in aerobic power. A non-significant improvement of 4% was found in the LD group. The CG group had a non-significant reduction of 4%.

## Strength

The number of repetitions for arm strength (Bråsterk test) was significantly ( $p < 0.01$ ) improved in the HIIT group, with an increase of 25%. Both LD (36%) and HIIT (24%) enhanced their leg strength significantly ( $p < 0.01$ ) judged by the number of repetitions in the Bulgarian Split Squat test. The duration of the stability test (core strength) improved significantly only in the LD group (22%,  $p < 0.01$ ), while the HIIT group increased non-significantly by 6%.

## Cardiovascular health and anthropometry

The spirometry variables did not change significantly during the project. In both the HIIT and LD groups, there was a significant drop in resting systolic blood pressure ( $p < 0.002$ ). For resting heart rate, the LD groups had a significantly lower heart rate post-test ( $p < 0.95$ ). There were no significant differences observed for body mass, waist and hip circumference, pre- and post-tests in either of the groups. A summary of changes from baseline to post-tests is described in Fig. 1.

## Effect size calculations

Effect sizes are often used as an alternative to significance testing to evaluate the importance of a change. When comparing the two intervention groups with the control group, an effect size of 0.50 or above was found for arm strength (LD), leg strength (LD), core stability (HIIT), systolic blood pressure (LD, HIIT), and diastolic blood pressure (LD). For pre- to post-development in the intervention groups, an effect size equal to or larger than 0.50 was found for arm strength (LD, HIIT), leg strength (LD, HIIT), core stability (LD), systolic blood pressure (LD, HIIT), diastolic blood pressure (HIIT), and maximal oxygen uptake relative to body mass (HIIT).

## Discussion

The HIIT group significantly increased in both endurance and strength. There was a significant improvement in LD group in strength-related variables, whereas there were no significant improvements observed in the control group. No difference in development between sexes could be seen.

## Anthropometric data

In contrast to previous studies that have showed a significant reduction in BMI and body fat with NW, there were no significant changes reported in anthropometric data between pre- and post-test for the training groups. Fabre et al. [23] observed that both NW and walking were sufficient to reduce

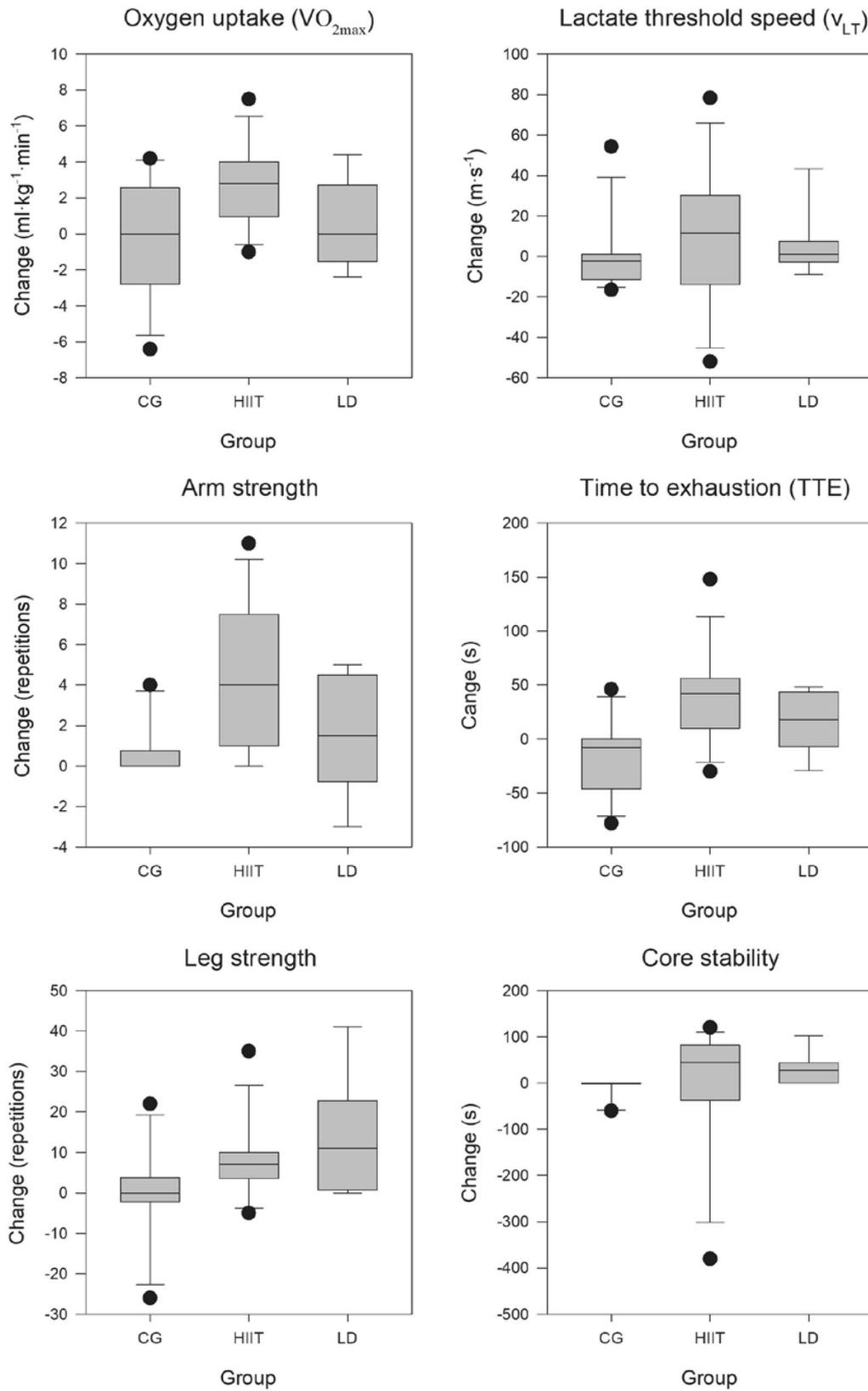
body mass, body fat, and diastolic BP in groups of obese women training three times a week for 12 weeks. However, our participant groups were non-obese and therefore a reduction in body mass or body fat is less likely to show in the relatively short time interval of this investigation.

## Blood pressure

Increased physical activity has proven beneficial in controlling blood pressure in hypertensive individuals [24]. Moreover, So et al. [25] discussed in their work that physical activity has a positive influence on blood pressure in non-obese adolescents. Interestingly, the present study revealed a significant reduction in systolic blood ( $BP_{sys}$ ) pressure in the two training groups. This is despite the fact that the initial values were within the normal range. We also observed a decrease in the  $BP_{dia}$  of HIIT and LD groups and while the results were non-significant, they may still have a clinical impact. In accordance with Molmen-Hansen et al. [26], who observed blood pressure was equally reduced after 1 time of 4 min with HIIT as from 4 times of 4 min HIIT, the significant decrease in  $BP_{sys}$  and a possibly clinically important reduction in  $BP_{dia}$  within the HIIT group may imply that even limited training at very high intensity can profoundly reduce cardiovascular risk factors, by increasing the pump capacity of the heart.

## Maximal aerobic power

It was observed that the HIIT group with just 1 1/3 h of total training in 2 months had significantly enhanced their oxygen uptake by 6%. Gist et al. [27], have found interval training to produce a similar increase in aerobic power as moderate intensity exercises in healthy individuals with a much shorter training time. The study of Weston et al. [28] proposed that in populations with lifestyle-induced diseases, high-intensity interval work proved to be better for developing aerobic power than lower intensity training. Our findings, therefore, appear to be consistent with previous studies that used running as exercise modus. Unfortunately, we have not found any studies that have discussed the training of aerobic power with tyre-pulling, whereas the effect of NW on aerobic fitness has been investigated in many settings and with diverse groups of people. Kocur et al. [29] concluded that NW was superior to normal walking in a group of cardiac rehabilitation patients in enhancing exercise capacity. Takeshima et al. [8] argued a similar training response from NW compared to ordinary walking in elderly people on aerobic fitness. Tschentscher et al. [30] likewise reported beneficial effects of NW on maximal oxygen consumption in a review article on health benefits of NW. Pellegrini et al. [31] also reported that NW produced a higher oxygen uptake than walking at the same speed, and attributed this



**Fig. 1** Changes from baseline to post-test

to the larger engagement of arms in NW. In a review article, Perez-Soriano et al. [32] reported an increased oxygen uptake from NW in comparison to ordinary walking. Also, Figard-Fabre et al. [33] argues that NW increases energy consumption when compared to normal walking, especially if NW technique is taught on beforehand. Church et al. [34] reported a 20% increase in oxygen uptake with NW when compared with normal walking. Porcari et al. [35] found that the use of “power poles” provides an increase in work intensity of approximately 23% ( $4 \text{ mL kg}^{-1} \text{ min}^{-1}$ ) as compared to ordinary walking at the same speed. They also reported 22% higher caloric expenditure ( $1.5 \text{ kcal min}^{-1}$ ). Hansen and Smith [36] found that NW increases the energy expenditure by 67%. However, this increase was much dependent on the way NW was performed, i.e., with a deep walking/jumping motion (“elghufs” in Norwegian) which is used by cross-country skiers. This method is much different from normal walking strides. Schiffer et al. [37] reported a more modest increase, in line with our findings, (8%) in oxygen uptake in NW when compared with normal walking.

Therefore, NW has appeared as an efficient mode of exercise to increase cardiovascular fitness, and we cannot find any reason that pulling tyres would diminish this effect. The  $O_{2\text{max}}$  result shows a significance within-group effect in the HIIT group with almost  $3 \text{ mL kg}^{-1} \text{ min}^{-1}$  (6%) increase. Therefore, our findings underline the earlier findings that high-intensity training is a good method to increase aerobic power in a short period of time, as claimed by Tjønnå et al. [38]. High aerobic power is known to be an important factor to prevent cardiovascular diseases, and training that enhances  $O_{2\text{max}}$  should be included in a training program for health promotion [39]. The present study indicated that less than 5 min of maximal intensity training, including the pauses, three times a week for 2 months can give a significant positive effect on aerobic fitness. The LD group reported a smaller, non-significant improvement, but the improvement may be clinically relevant. This type of training should therefore not be dismissed, as some may prefer less intense activity. Tyre-pulling should also reduce the possibility of injury as it can be performed at lower speeds, but with the same energy requirement. Our findings show that people with joint problems may use tyre-pulling with high-intensity while still walking and with acceptable joint loading.

### Lactate threshold speed

Lactate threshold performance is regarded as a valid sign of endurance capacity [40]. An enhanced lactate threshold performance may give the person the ability to work at a higher intensity without early fatigue [40], or keep the work load unchanged, but with a lesser degree of perceived exertion. The result of a lactate threshold test is influenced

by the individual maximal aerobic power, the utilisation of maximal aerobic power and movement efficiency. The HIIT group increased their  $V_{\text{lt}}$  by  $0.12 \text{ m s}^{-1}$  and the LD group by  $0.10 \text{ m s}^{-1}$ . This change is not statistically significant; however, the improvement may be of practical importance as one now can run at a somewhat faster pace at the same exertion level. We found both enhanced aerobic power and increased utilisation, and this may explain the increased threshold velocity.

### Time to exhaustion

With an increase in  $O_{2\text{max}}$ , the time to exhaustion (TTE) also increases. The most popular treadmill test protocols, Balke and Bruce, are considered as indirect measures of maximal aerobic power, since a longer duration leads to a higher aerobic power [41]. However, the results may be biased when using time to exertion as criterium [42]. For the HIIT group, the increase in TTE amounted to 33 s. The oxygen uptake is expected to increase with  $\sim 4 \text{ mL kg}^{-1} \text{ min}^{-1}$  per step in this protocol, so this increase in running time fits well with the increase in oxygen uptake that we have found ( $3 \text{ mL kg}^{-1} \text{ min}^{-1}$ ). The LD group increased TTE with 19 s, which still can be of practical importance.

### Strength

One of the main aims of this study was to establish the effect of tyre-pulling on muscle strength. The use of walking poles while pulling an object offers training of the upper body and arms, as well as legs. This makes tyre-pulling possibly time efficient as both endurance and strength may be trained simultaneously, giving a total body workout. Shim et al. [43] measured EGM activity of upper body and lower body muscles when walking normal and when using walking poles. Using poles significantly increased the muscle activity in upper body muscles, but not in lower body muscles. Also, Song et al. [44] found beneficial effects of NW on arm strength in elderly women. If one in addition pulls a heavy object, it is reasonable to think that leg muscles would also be involved more than when just walking ordinary or with poles. Although we have no measurements of force when using the poles, our results indicate that the load on the body through tyre-pulling is sufficient to create increased strength in both arm/shoulder muscles and legs. The HIIT group increased significantly (23%) in arm strength. This may be due to the large demands on arm strength when sprinting with poles. The LD group had, as expected due to a larger temporal stimulus, the largest improvement of leg strength (36%). And despite the short training duration in HIIT, leg strength improved by 20%, an improvement of both practical and statistical significance.

In core strength, only the LD group had a significant increase, with 20%. Here the explanation may be that the constant drag and the rhythmic holding of the trunk at each stride may have given efficient training to the core abdominal musculature. With a longer training time for the LD group, the training stimuli also got larger. Walking through uneven terrain may require frequent adjustments of body position, unlike the sprints that were performed on an asphalt surface. It should be noted that the HIIT group also improved in core strength, but due to a larger variance within the group, the result was not statistically significant, but an improvement of 12 s is noteworthy, especially as the initial value was much higher than for the LD group, 191 vs. 128 s. In all, we explain the observed difference in strength results between the two training groups by the way arms and legs are used in sprint and long-distance training, and the time used.

### Effects of training duration

Tjønnå et al. [38] found similar responses to training  $1 \times 4$  min (120 min exercise time) and  $4 \times 4$  min (480 min of exercise time) at 90% of  $HR_{max}$  for three times each week and 10 weeks in untrained males (age 42 years) for  $O_{2max}$ , blood pressure and body fat. This implies that a large training load may not be necessary to improve physical health in untrained adults. Our group was about half that age (23 years) and with an oxygen uptake of  $49 \text{ mL kg}^{-1} \text{ min}^{-1}$ ,  $7 \text{ mL kg}^{-1} \text{ min}^{-1}$  more (or  $\sim 15\%$ ) than the participants of Tjønnå et al. [38]. Even with a total training time of 120 min ( $0.5 \text{ min} \times 10 \times 3 \times 8$ ), including rest time, the oxygen uptake improved significantly within an 8-week time span. The use of high-intensity training therefore seems to be useful not only for less fit persons, but also for people of average fitness. The present HIIT protocol consisted of less than 5 min of exercise each session including pauses. Wisløff et al. [45] used HIIT on patients with heart diseases,  $4 \times 4$  min interval runs at 90% of  $HR_{max}$ , with 3 min active rest in between. The authors concluded that exercise intensity is an important factor for developing aerobic power. Also, Weston et al. [28] point to the importance of high training intensity in their meta-study.

### Practical application

The present study indicates that tyre-pulling may serve as an upper as well as a lower body exercise providing an effect on strength and endurance capacity. The LD training gave improved muscular endurance in core strength and in legs, but no significant improvement in  $O_{2peak}$ . The HIIT training gave increased endurance, and arm and leg strength, but not better strength in core musculature. Overall, the tyre-pulling method appeared beneficial for improving both aerobic power as well as endurance strength in arms and legs, using

either long-distance, low-intensity training, or high-intensity interval training.

### Limitations

#### Dropout

As in many demanding exercise studies, the present investigation witnessed a dropout in both exercise groups. Despite this, the significant change in the variables of interest indicates a significant difference from baseline.

#### Standardised strength tests

A major limitation of the strength tests is the lack of standardisation. Even though the modified abdominal plank stability test is formalized as an exercise test, no validation has been done in the form of using it as an endurance strength test. The “Bråsterk” is not standardized in any way, but there are few tests available for this specific kind of arm movement. We still believe this test provides a good indication of the effect of using walking poles together with tyre-pulling, but future validation studies must confirm this. The Bulgarian Split Squat test, on the other hand, is standardised and may serve as a test for improved leg strength after tyre-pulling training periods.

#### Weather and terrain

The load from the tyres depends on surface friction, and this can change according to weather conditions. Moist weather will reduce gliding friction, making it less hard. The terrain surface is also important. For the high-intensity group, the sessions were done at the same, flat field every time. For those doing long-distance training, they had to find suitable routes out in the nature, and thus experienced varying conditions of friction as the path and/or the weather changed. This may have influenced the effect of the training, as each session could differ somewhat in intensity.

This study takes an ecological validity approach using two common training methods. We made no effort to equalise the groups regarding energy expenditure. This because we are not interested in whether one of the two modes are better than the other, but we wanted to see the effects of typical training modes performed with tyre-pulling.

### Conclusion

The results of this study showed that doing tyre-pulling either as a high-intensity activity with short duration, or as a low-intensity, long duration activity, was feasible in producing significant improvements in body strength and

endurance in healthy young people. Tyre-pulling could thus be one option to be considered when concurrent strength and endurance training is wanted.

### Compliance with ethical standards

**Conflict of interest** The authors declare no competing financial interest.

**Human and animal rights** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Participants gave written informed consent before starting the study.

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