Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

Rebekka Resell Mauring

The Effect of CrossFit® vs. Conventional Training on Maximal Oxygen Consumption: A Randomized Controlled Trial

Master's thesis in Physical Activity and Health,
Specialization Exercise Physiology
Supervisor: Vegard Moe Iversen
Co-supervisor: Marius Steiro Fimland

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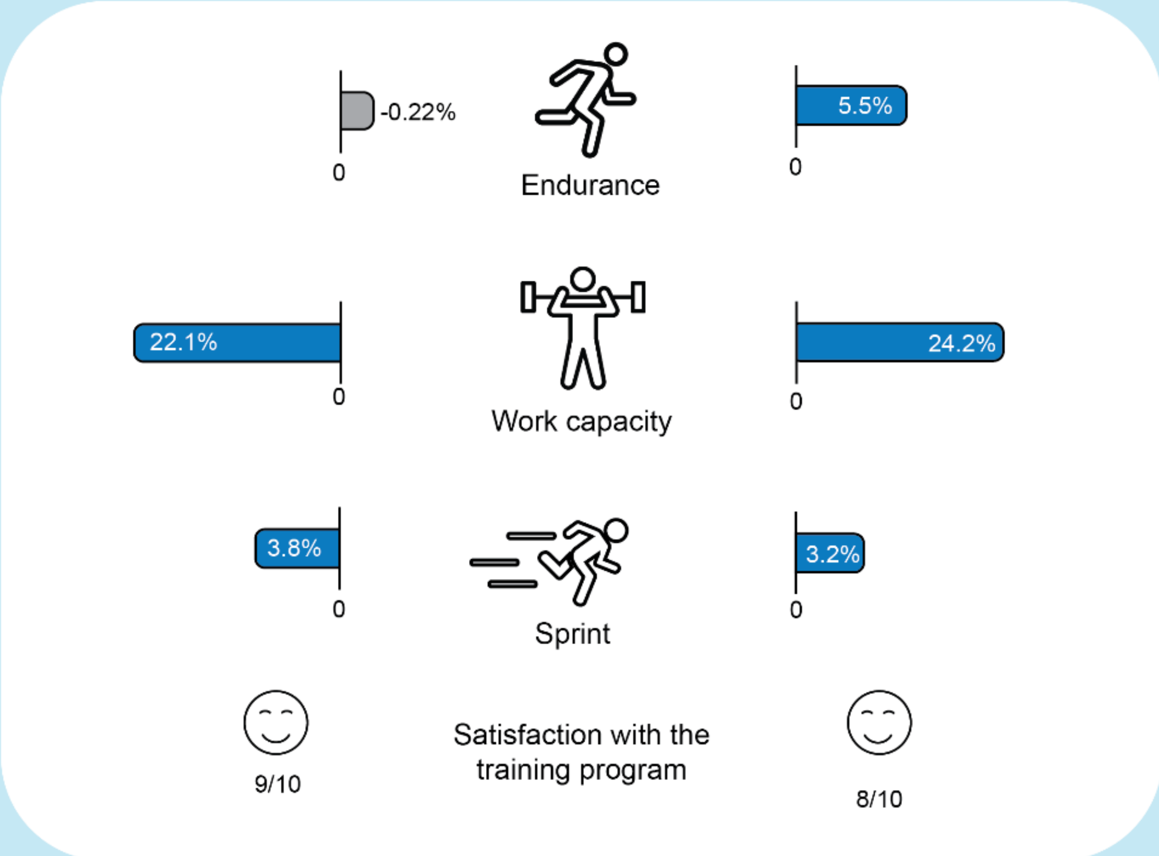
CrossFit
vs.
Conventional Training:
A Randomized Controlled Trial

29 participants were randomized to 8 weeks of either CrossFit or conventional endurance and strength training (4x3 min high intensity interval training (HIIT) and strength exercises).

This is what we found out:

CrossFit | Conventional training



Conclusion:
If you aim to improve your endurance, HIIT is your best option. The HIIT program allowed a higher intensity as the excercises were not as technical as the ones in the CrossFit program. For improving work capacity and sprint, the groups were equally effective.

As most of the participants were curious about CrossFit, the CrossFit program scored a higher degree of satisfaction.

*CrossFit also claims to improve other physical skills, which were not investigated in this study.

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Abstract

Background. CrossFit® is a rapidly growing high intensity functional training modality, with the aim of improving several physical parameters such as aerobic endurance, speed and muscular strength. Few studies have compared CrossFit® with other exercise modalities, and no studies have compared CrossFit® with high intensity interval training (HIIT). In this study we compared the effect of CrossFit® with conventional training, including a HIIT component, on aerobic capacity, work capacity and sprint performance. Furthermore, we compared the participant's degree of satisfaction throughout the training period.

Methods. Thirty-six, healthy men and women were randomized to eight weeks of either CrossFit® or conventional training three times a week at a CrossFit® affiliate. The CrossFit® group were assigned a new workout every session combining endurance, weightlifting, and gymnastics elements. The conventional training group were assigned a 4x3 minutes HIIT on the treadmill and a weightlifting routine including back squat, bench press and standing bent over rows every session. To compare the effects of the two workout modalities, the main outcome was between group changes from baseline to posttest in peak oxygen consumption (VO_{2peak}), measured using a graded exercise test on a treadmill. Secondary outcomes were between group changes from baseline to posttest in work capacity and sprint performance, as well as degree of satisfaction throughout the training period. These parameters were measured respectively using a timed CrossFit® workout, a 200-meter sprint and a subjective questionnaire.

Results. Twenty-nine participants completed the posttest measures and were included in the analysis. Between group changes were only observed in VO_{2peak} favoring conventional training (Mean change: 2.43 $mL*kg^{-1}*min^{-1}$, CI: 0.46-4.4, $p<0.05$). The conventional training group improved their VO_{2peak} by 5.5%, whereas the CrossFit® group did not improve in VO_{2peak} (-0.22%). There were no significant differences between groups in work capacity (Mean change: 0.38 min, CI: -0.72-1,5, p=0.49) and sprint performance (Mean change: 0.23 sec, CI:-1.4-0.97, p=0.69). The CrossFit® group improved by 22.1% and 3.8% respectively, while conventional training improved by 24.2% and 3.2%, respectively. Both groups reported a high degree of satisfaction, but the CrossFit® group reported a higher satisfaction in one of the questions regarding the training intervention (one point higher on a 1-10 scale).

Conclusion. The conventional training group exhibited greater VO_{2peak} improvements, which indicates that HIIT could be more effective than CrossFit® in eliciting change in the aerobic system. The findings in this study suggest similar performance benefits between CrossFit® and conventional training in terms of work capacity and sprint performance. CrossFit® participants may have a higher degree of satisfaction due to its varied training form, and this could lead to a greater adherence to the training modality. The effect of selection bias on satisfaction due to participants wanting to try CrossFit® should be taken into consideration.

Abstrakt

Bakgrunn. CrossFit® er en voksende type høy-intensiv funksjonell treningsform, med mål om å forbedre flere fysiske parametere som aerob utholdenhet, fart og muskelstyrke. Få studier har sammenlignet CrossFit® med andre treningsformer, og ingen studier har sammenlignet CrossFit® med høy-intensiv intervalltrening (HIIT). I dette studiet sammenlignet vi effektene av CrossFit® med konvensjonell trening med en HIIT komponent, på aerob kapasitet, arbeidskapasitet og sprintprestasjon. Videre sammenlignet vi deltakernes grad av fornøydhet gjennom treningsperioden.

Metode. Trettiseks unge, friske menn og kvinner ble randomisert til åtte uker med enten CrossFit® eller konvensjonell trening tre ganger i uka på et CrossFit®-senter. CrossFit® gruppen utførte en ny økt hver gang med elementer fra utholdenhet, vektløfting og gymnastikk kombinert. Den konvensjonelle treningsgruppen gjorde 4x3 minutter HIIT på tredemølle og øvelsene knebøy, benkpress og stående roing hver økt. For å sammenligne effekten av de to treningsformene var hoved-utfallsmålet endring mellom gruppene fra baseline til posttest i peak oksygenopptak (VO_{2peak}), målt med en gradert treningstest på en tredemølle. Sekundærmål var endring mellom gruppene fra baseline til posttest i arbeidskapasitet og sprintprestasjon, samt grad av fornøydhet i løpet av treningsintervensjonen. Disse parameterne ble henholdsvis målt gjennom en tidsstyrt CrossFit® økt, 200m sprint, og et subjektivt spørreskjema.

Resultat. Tjueni deltakere gjennomførte posttestene og ble inkludert i analysene. Forskjell mellom gruppene var kun observert i VO_{2peak} og favoriserte den konvensjonelle treningsgruppa (Gjennomsnittlig endring: 2.43 $mL*kg^{-1}*min^{-1}$, CI: 0.46-4.4, $p<0.05$). Den konvensjonelle treningsgruppa forbedret seg med 5.5%, mens CrossFit® gruppa forbedret seg ikke (-0.22%). Det var ingen signifikant forskjell mellom gruppene i arbeidskapasitet (Gjennomsnittlig endring: 0.38 min, CI: -0.72-1,5, $p=0.49$) og sprint prestasjon (Gjennomsnittlig endring: 0.23 sec, CI:-1.4-0.97, $p=0.69$). CrossFit® gruppa forbedret seg henholdsvis med 22.1% og 3.8%, og den konvensjonelle treningsgruppa med 24.2% og 3.2%. Begge gruppene rapporterte en høy grad av fornøydhet i ett av spørsmålene om treningsintervensjonen (ett poeng høyere på en skala fra 1-10).

Konklusjon. Den konvensjonelle treningsgruppa hadde større forbedringer i VO_{2peak} enn CrossFit® gruppa, noe som indikerer at HIIT kan være mer effektiv enn CrossFit® i å framkalle endringer i det aerobe systemet. Funnene i dette studiet foreslår lignende prestasjonsforbedringer mellom CrossFit® og konvensjonell trening når det kommer til arbeidskapasitet og sprint prestasjon. CrossFit® deltakere kan muligens vise en høyere grad av fornøydhet på grunn av den varierte treningen, og dette kan gi en høyere tilknytning til treningsformen. På grunn av effekten av seleksjonsbias der deltakerne ønsket å prøve CrossFit® må dette tas med i betraktningen.

Acknowledgment

I would like to thank the other master student cooperating in this project, Ingrid Bårtvedt, who made this project feasible and fun. I would also like to thank my supervisors Vegard Moe Iversen and Marius Steiro Fimland, as well as Thomas Fremo and Arnt Erik Tjønna for guidance and training in the exercise lab. I am so thankful for all the help from people at Maxpuls; Esten Heggem for help with the programming of the CrossFit® intervention, Ole Thomas Trobe for help throughout the project, Márk Leskó and Kristian Lundstad Stavik for advice about technique in exercises and CrossFit® in general, Ketil Inderberg for renting of Maxpuls, and Anders Holmberg for photographing the illustrations of the exercises. Thanks to my friends and family who supported me throughout this period and for helping me out with formulations and wording in this thesis. Lastly, I would give a great thank you to all the volunteers, for their time and effort in this project. This project would not be possible without all these people.

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Abbreviations

AMRAP	As many rounds as possible
CI	Confidence interval
EMOM	Every minute on the minute
HIIT	High intensity interval training
HR	Heart rate
HR_{max}	Maximal heart rate
SD	Standard deviation
VO_2	Oxygen consumption
VO_{2max}	Maximal oxygen consumption
VO_{2peak}	Peak oxygen consumption

1. Introduction

CrossFit® is one type of high intensity functional training that has increased in popularity over the last two decades (1). CrossFit® was founded by Greg Glassman in 2001 (2) and has developed into a global community where people encourage and motivate each other to reach their goals (3). In CrossFit®, human performance is measured through fixed workouts which are often measured by counting the repetitions or rounds of movements performed in a predetermined amount of time, or a set amount of repetitions or rounds as fast as possible (2). CrossFit® includes both endurance and resistance exercises in the same session and can be regarded as concurrent training (4). Due to high repetition volume, high speed and lower loads on the exercises, it has been claimed that CrossFit® leads to improved aerobic and anaerobic endurance, as well as muscular strength development (5). While conventional training aims to improve one physical component at the time (e.g. aerobic endurance), the goal of CrossFit® is to be a general and varied exercise modality that improves all of the 10 physical skills; cardiovascular/respiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance and accuracy (6). Most of the previous research done on CrossFit® focuses on the effects of these skills and have found a positive physiological impact on aerobic capacity, work capacity and anaerobic capacity (7-10). However, there have been various conclusions about these effects (11, 12). More studies about CrossFit® are needed, and the focus of this study is therefore to investigate the relationship between CrossFit® and potential cardiovascular changes.

Since CrossFit® is a type of concurrent training, a comparison with a more traditional modality of concurrent training is investigated in this study. High intensity interval training (HIIT) and resistance training can be performed in the same session, where the focus is improved endurance and muscular strength (13). This can be regarded as conventional endurance and resistance training. HIIT generally refers to repeated short exercise bouts, performed at high intensity near maximal effort (≥80% of HR_{max}), separated by a set time of low intensity exercise or rest (14, 15). The intervals can last from a few seconds up to several minutes, depending on the intensity. Even if the total duration of high intensity exercise bouts is short, running performance has been shown to improve significantly with HIIT through improved aerobic energy metabolism (14). This is linked to peripheral adaptations, such as skeletal muscle mitochondrial content and capillary density, as well as central factors such as maximal stroke volume, maximal cardiac output and blood volume (15). These adaptations depend on exercise volume, which is the product of intensity, duration and frequency. There is evidence that exercise intensity is important for increasing VO_{2max} when comparing HIIT with time-matched moderate intensity (15). This reflects HIIT as a time-efficient endurance modality. HIIT and CrossFit® share the similar time-efficient high intensity training format, but CrossFit® differs from HIIT as it incorporates a variation of functional exercises with different time duration and rest, instead of the unimodal exercise form utilized in HIIT. These differences could result in different physiological adaptations between the two training formats, as CrossFit® challenges multiple body systems during one session (1). However, similarly to HIIT, the high intensity present in CrossFit® exercises also targets the aerobic system (5, 10).

To compare CrossFit® with HIIT could contribute to new knowledge about the associated performance benefits in CrossFit® as HIIT is already known to yield great improvements in aerobic endurance. To my knowledge, only one other study has compared CrossFit® with concurrent training on aerobic endurance (16). The study protocol in the concurrent training group included moderate endurance training (60-80% of HR_{max}) on the treadmill directly followed by resistance training in 30 participants. After 8 weeks, the CrossFit® and concurrent training group improved their VO_{2max} with 36% and 26% respectively. The study found no significant differences in improved VO_{2max} between the groups, but the results showed a tendency to a slightly higher improvement in VO_{2max} in the CrossFit® group. Because CrossFit® targets a high volume of fitness components in a short time, Bahremand and colleagues concluded that this would lead to a greater aerobic demand, more so than moderate endurance training. Another study compared CrossFit® endurance (CrossFit® combined with HIIT) with 12 weeks of combined long-distance running and HIIT training in 21 recreational runners (17). Both groups improved their 5-km running performance similarly, but the long-distance running group had a greater improvement in VO_{2max} than the CrossFit® group because of a greater volume of running. It should be mentioned that two meta-analyses (18, 19) found few CrossFit® studies with high quality and low bias on the relevant aerobic parameters (i.e. aerobic capacity, anaerobic capacity and work capacity) further justifying studies such as this current one.

As no other studies have compared CrossFit® with this type of conventional training, the main aim of the study was to investigate the effect of CrossFit® compared to conventional training (4x3 min HIIT and strength exercises) on VO_{2max}. Work capacity, sprint performance and degree of satisfaction were investigated as secondary outcomes. We expected that the conventional training group would have a greater improvement in VO_{2max} than the CrossFit® group due to the central adaptations yielded from the running specificity in HIIT. The CrossFit® group was expected to improve more in sprint performance and work capacity due to the explosive and varied movements involved. A higher degree of satisfaction was also expected from CrossFit®, as a previous study has shown higher degree of satisfaction from CrossFit® compared to concurrent training (20). Both groups were expected to improve in all of the measured parameters.

2. Methods

2.1. Study Design

This study was a randomized controlled trial, performed in Trondheim, Norway. Pre- and post-testing of VO_{2max} was performed at the Next Move core facility at St. Olav's Hospital (NTNU, Norwegian University of Science and Technology). Sprint, medicine ball throw and long jump were performed at Ranheimshallen. The remaining tests and the training intervention were performed at CrossFit Maxpuls. All tests and trainings were supervised by two master students in Physical Activity and Health, certified Level 1 CrossFit® instructors. The study was approved by the Institutional Review Board at NTNU. The privacy management was approved by the Norwegian Centre of Research data (NSD) and followed in accordance with ethical guidelines from the declaration of Helsinki.

Accounting for dropouts, 36 participants were included and randomized into two groups: a CrossFit® group (n=18) and a conventional training group (n=18). Randomization (1:1) was performed by a web-based randomization system developed and administered by Clinical Research Unit Central Norway, The faculty of Medicine and Health Sciences, NTNU, Trondheim, Norway. Both groups were divided into two replicate groups who trained at different times during the daytime every Monday, Wednesday and Friday. Throughout the testing and the training intervention, the participants were asked to avoid any endurance and strength training.

2.2. Participants

The participants were recruited through advertisement on social media, posters at NTNU campus and CrossFit Maxpuls, and through visit to lectures at NTNU. Inclusion criteria were 1) healthy adults without injuries within the age of 18-30 years old, 2) previous experience with endurance and/or resistance training approximately 1-3 times per week the last 6 months, and 3) no experience with CrossFit® beforehand. An eligibility form (Appendix 1) was filled out by the participants that met the inclusion criteria. All participants received information about the study and signed a consent form (Appendix 2) before participating. The participants were informed that they could withdraw from the study at any time without the need to provide a reason.

2.3. Training intervention

All participants had three supervised trainings per week for eight weeks, each lasting one hour. Before the pre-testing, all participants had to do 3.5 hours of familiarization. They learned the essential movements used in the tests, and exercises customized for their intervention group (Appendix 3). Figure 1 present a timeline of the 13 weeks of the project.

Figure 1: Timeline of the project; inclusion and randomization of the participants, familiarization of the exercises used in the intervention, two weeks of pre- and posttests and eight weeks of training intervention.

2.3.1. CrossFit® group

The CrossFit® group did 24 different sessions, following the CrossFit® template (2), alternating with the elements metabolic conditioning, gymnastics and weightlifting. Monday was a one-element day, Wednesday a two-element day and Friday a three-element day. The full programming is presented in Table 1 with examples of the exercises in Appendix 4. Generally, the sessions were divided in two. Part one consisted of a general and specific warm-up, followed by technique training and a test round of the workout of the day. The warm-up exercises were mixed depending on the session (Appendix 5). Part two consisted of an intensive workout, often performed as many rounds as possible (AMRAP), every minute on the minute (EMOM) or as fast as possible (For time). In an "AMRAP" the purpose is to do as many repetitions/rounds as possible in a predetermined time. An "EMOM" have one or more exercises in a set repetitions that should be performed within one minute before proceeding with the same or another exercise the next minutes. In "For time", a set repetitions of exercises should be performed as fast as possible. The participants wrote their performance (time to complete or number of repetitions) on the whiteboard after every session. We tried to use the exercises equal number of times during the intervention. Degree of difficulty of the exercises was gradually increased during the intervention. Workouts were made by a combination of exercises and number of repetitions to fit the group. Each participant adjusted their own weight individually, and sometimes a version of the exercise (e.g. ring rows instead of pull-ups) and number of repetitions.

Table 1: CrossFit® programming for the eight weeks of training. M=metabolic conditioning, G=gymnastics, W=weightlifting.

Week	**Monday (one-element)**	**Wednesday (two-elements)**	**Friday (three-elements)**
1	***M*** **Rowing:** 4 x4 min intervals 3 min active break between	***GW*** **Front squat:** Build up to 2RM. 3+3, 2+2, 1+1 (1 fast + 1 slow) **3 RFT:** 15 Front squats 25 Push-ups**	***MGW*** **AMRAP20:** 10 Burpees 15 Box jumps 20 Ground to overhead 200m Run
2	***G*** **Kipping practice** **EMOM10:** 1. 4-7 Toes to bar** 2. 16-20 Lunges	***WM*** **E2MOM10:** 2-6 Hang power clean w/increasing load **For time:** 21-15-9 Hang power clean Assault bike	***GWM*** **AMRAP20:** 20 Air squats 10 Push press 15/12cal Row
3	***W*** **Deadlift:** 5x5 w/increasing load **EMOM8:** 8-12 Burpees **Tabata 20/10 sec**: 2x (Sit ups, toe touch, tuck ups, side crunches), tuck up hold Wall sit 1 min	***MG*** **Kipping pullups practice** **For time:** 400m Run 21-15-9 Pull-ups**	***WMG*** **AMRAP20:** 20 Wallballs 20 Sit-ups 20 Dumbbell hang power clean and press 20 Lunges 20cal Assault bike

4	***M*** **“Fortitude”*** **EMOM30:** 12/10cal Row 10 Burpees	***GW*** **Front squat:** 4x4 **5 RFT:** 12 + 12 Overhead lunges 10 Toes to bar**	***MGW*** **AMRAP20:** 200m Run 15 Push-ups** 15 Deadlift
5	***G*** **Handstand practice** **“Death by Burpee”** **EMOMX:** 1. 4 Burpees 2. 5 Burpees 3. 6 Burpees etc. until exhaustion	***WM*** **E2MOM10:** 3-6 Power cleans **5 Rounds for time:** 10 Power cleans 10 Burpees	***GWM*** **“Jackie”*** **For time:** 800m Row 35 Thrusters 20 Pull-ups**
6	***W*** **“Big clean complex”*** **On the 5:00 x 6** 3-position Squat clean Push press 3-position Squat clean Push jerk 3-position Squat clean Push jerk	***MG*** **“Bert”* Team of 2** 50 Burpees 500m Row 100 Push-ups** 500m Row 150 Walking lunges 500m Row 200 Air squats 500m Row 150 Walking lunges 500m Row 100 Push-ups** 500m Row 50 Burpees	***WMG*** Buy in: 600m Run **EMOM18:** 1. 10 Deadlift 2. 15 Kettlebell Swing 3. 10-12 Toes to bar** Buy out: 600m Run
7	***M*** **Trisprint (Team of 2)** **AMRAP4 x 5** 30 Shuttle runs (10m) 22/16cal Row Max cal Assault bike	***GW*** **Kipping practice** **‘’Fran’’** 21-15-9 Thrusters (35/25kg) Kipping pull-ups**	***MGW*** **AMRAP30 (Team of 2)** 40cal Assault bike 40 Wallballs 40 Burpee box jumps 40 Dumbbell single arm Push press
8	***G*** **Muscle ups practice** **EMOM12:** 1. 3-5 Ring dips** 2. 3-5 Pull-ups** 3. 8-10 Box jumps	***WM*** **Clean and jerk** Build to 3RM **EMOM10:** 1. 6-8 Clean and jerk 2. 8-12cal Row **Handstand practice**	***GMW*** **“Lumberjack”*** 20 Deadlift 500m Row 20 Kettlebell Swing 500m Row 20 Front squats 500m Row 20 Burpees 500m Row 20 Pull-ups* 500m Row 20 Box jumps 500m Row 20 Dumbbell squat cleans 500m Row

*Jackie, Bert and Big clean complex are adjusted. Lumberjack are modified from run to row.
**Adjusted options for pull-ups=ring rows, jumping from box, banded. Ring dips=dips from box, banded. Push-ups=hands on a box. Toes to bar=Knees to chest, knee raises.

RM=repetition maximum. E(2)MOM=Every (second) minute on the minute, AMRAP: as many rounds as possible.

2.3.2. Conventional training group

The conventional training group performed the same endurance and resistance training every training session. The participants alternated between starting with endurance followed by resistance training, and resistance followed by endurance training. For the endurance part, they ran 4x3 min intervals on a treadmill (Life Fitness, 95T Treadmill, Table 2). The zones in the intervals were based on measured HR_{max} from the VO_{2max} test, adding 3-5 beats to reflect the real HR_{max}. A Polar H10 heart rate transmitter (Polar Electro, Kempele, Finland) was connected to the associated application "Polar Beats" on the mobile phone to measure the heart rate during the intervals. An example of the heart rate during the intervals in the conventional training group is presented in Appendix 6.

Table 2: Endurance training for the conventional training group; warm-up, intervals, active recovery and cool down. HR_{max}=maximal heart rate.

Endurance training	Time and intensity
Warm-up	5 min, 70% of HR_{max}
Intervals	4x3 min, 85-95% of HR_{max}
Active recovery	2 min, 70-75% of HR_{max}
Cool down	2 min

The resistance training is explained in detail in another master thesis (21). In short, participants performed three sets of 8-12 repetitions of back squats, bench presses and standing bent over rows.

2.4. Testing and outcome measures

All participants got a standard encouragement to max effort during the testing and training. Pre- and post-testing made a total of four weeks; two weeks of pre-testing and two weeks of post-testing. All tests were performed within these two weeks, and it was approximately 48 hours between each test day. Participants had to refrain from all exercises with high intensity 24 hours before the tests. VO_{2max} and body composition were measured during the first week. The second week, sprint followed by the power tests were performed the same day. On separate days, strength measurements and work capacity were measured, respectively. The protocols for the tests of maximal strength in half squat and bench press, and upper and lower body power (medicine ball throw and standing long jump) are described in more detail in the other student's master thesis (21).

2.4.1. VO_{2peak}

VO_{2peak} was measured with a graded exercise test to exhaustion, using the cardiopulmonary exercise test on a treadmill (Woodway PPS 55, Waukesha, WI, USA). This test is shown to be a valid and reliable measure of VO_{2max} (22). Prior to the test, height and weight were measured and the participants performed a 10-minute warm-up with a speed of their choice, gradually increasing the speed and incline. The start of the test was based on the ending speed from the warm-up with an incline of 6%. A face mask was fitted to each participant (7450 Series V2 CPET mask, Hans Rudolph, Shawnee, KS, USA). The speed was increased 1 km per hour every minute about 3-4 times, then increasing the incline with 2% up to three times until exhaustion. If exhaustion was still not reached, the speed was again increased by 1 km per hour per minute until exhaustion. A Borg scale from 1-10 (Appendix 7) was used to measure rate of perceived exertion (23). VO_{2peak} was found from the average of the three highest VO_2 values from the test. The main criteria for VO_{2max} was to reach a plateau of VO_2, where the VO_2 did not increase with increasing intensity (24). In addition, a respiratory exchange ratio>1.05 should support the main criteria. Rate of perceived exertion was used to give a subjective confirmation of exhaustion, and a rate of perceived exertion >9 could support the criteria. Multiple participants did not reach a plateau in VO_2, therefore the highest measured values of VO_2 are noted as VO_{2peak}.

An ergospirometry system with a mixing chamber (Metalyzer II, CORTEX Biophysik GmbH, Leipzig, Germany) measured VO_2 and respiratory exchange ratio every 10-seconds. The maximal heart rate (HR_{max}) was measured with Polar H7 and H10 heart rate (HR) transmitters (Polar Electro, Kempele, Finland), as the highest measured HR during the test. Before every test, the apparatus was calibrated based on humidity conditions, ventilation (3L Calibration Syringe, Hans Rudolph, Lenexa, KS, USA) and ambient air. Between every 3-4 tests, the apparatus was calibrated based on the barometric pressure from a weather station (Oregon Scientific, Tualatin, OR, USA), and a reference gas mixture (5.00% CO2 and 15.00% O2, HiQ AGA, Norway).

2.4.2. Work Capacity

Work capacity was measured with the exercises thrusters and burpees (Figure 2) in the format 21-15-9 repetitions for time. This meant that 21 thrusters were completed before proceeding to 21 burpees, then 15 thrusters etc. down to nine repetitions, as fast as possible. The results were measured as time to complete all the repetitions. Thrusters were performed with a 15 kg and 20 kg barbell (Play, Play Sport AS) for the women and men, respectively. The men added weight plates (Gymleco, Gym Sport AS) to a total of 30 kg in the test. Thrusters were performed by doing a front squat, then stretching out the hip and pressing the barbell overhead (Figure 2a). The bottom position in the squat was measured individually with tape on a stick, indicating their depth for every repetition in the thruster. The depth was preferably below the knees depending on their squat mobility. If they were not able to squat lower than their knees, their position was measured as how deep they were able to squat. Burpees started in a standing position before the hands were lowered to the floor and feet kicked out until the chest touched the floor (Figure 2b). From the floor, the participants jumped or walked up towards their hands and jumped to a target in the rack (Gym Sport AS) based on their height, touching with both hands. Before starting the test, one test round of five thrusters and burpees was completed. Rate of perceived exertion was measured directly after the last repetition.

Figure 2: Illustration of a) thrusters and b) burpees to target. Photo: Anders Holmberg

The warm-up included a general and specific part. The general part consisted of the following exercises for 30 sec each: shuttle runs, active samson, active spiderman, squat to stand with arms up, air squat and pass throughs (Appendix 5). The specific part consisted of front squat, push press and thrusters for five repetitions each with a PVC pipe, then 3x2 repetitions with the barbell.

2.4.3. Sprint performance, Anthropometrics and Degree of Satisfaction

Sprint performance was assessed in a 200m sprint test in Ranheimshallen. Participants engaged in a 10 min warm-up with moderate running and some sprint accelerations. They were encouraged to sprint 10-20m all out before stopping, then rest and repeat 2-3 times during the warmup. A 200m maximal performance sprint test on the track field was completed, and time was taken to sprint one round.

Height was measured using a telescopic measuring rod (Seca, 222, Deutchland). Body weight (kg), muscle mass (kg) and fat percentage (%) was assessed using an Inbody 770 body composition and body water analyzer (InBody 770, BIOSPACE, Seoul, South Korea). The test was done between 7 and 9am. Before the measurements, the participants were instructed to visit the toilet and avoid any food and fluid intake, instructions from the InBody 770 user manual (25).

Degree of satisfaction was assessed at the start of week one, start of week five and end of week eight using a self-made questionnaire with a scale from 1-10 (Table 3). Six questions were answered regarding Q1: intervention, Q2: performance, Q3: challenge, Q4: motivation, Q5: adherence, and Q6: training status.

Table 3: To assess degree of satisfaction, a questionnaire of six questions was asked the first session, start of week five and last session, with a scale from 1-10.

Questions	
1	How satisfied are you with the training program?
2	How satisfied are you with your own performance at the training sessions?
3	How exhausting do you experience the training sessions?
4	How motivated are you for training right now?
5	How likely is it that you will continue training after the training period?
6	How do you think your training status is right now?

2.5. Pandemic considerations

Due to the pandemic, many precautions and adjustments occurred during the project. There was a maximum of 10 participants in one training group, and nobody could train if they were sick or in quarantine. The participants could retake one missed session on the weekends as soon as possible, in case of later quarantine, sickness or closing of the fitness center. They could perform a maximum of four training sessions during a week. Everyone kept a two-meter distance between each other, and the equipment was disinfected after the workouts. During testing, a minimum number of participants were tested at the same time. During the maximal oxygen test, a cleaning routine was carefully performed before and between the testing of each participant. We tried to avoid any physical contact with the participants when correcting the exercises or during testing.

2.6. Statistical Analysis

Statistical analyses were performed using the Software program IBM SPSS, version 26.0 (Statistical Package for Social Science, Chicago, IL, USA). All variables were checked for normality using Quantile-Quantile plots and histograms, as well as Shapiro-Wilks' test of normality. The graphs indicated normal distribution for all variables with exception of degree of satisfaction, and parametric tests were used. Independent sampled t-tests were used to assess differences in mean change from baseline to posttest between groups. To measure the effect of the test variables within the groups, a paired sampled t-test was used. Results are presented as means with 95% confidence intervals. The level of significance was $p \leq 0.05$ in all tests. The effect size (d) was calculated for the significant differences between the groups (Cohen's d). A small effect size is $d=0.2$, medium $d=0.5$ and large $d=0.8$. For graphs not normally distributed, a non-parametric test (Mann-Whitney) was used, and data are presented as median with interquartile range.

3. Results

3.1. Participant description

Among the 36 participants randomized to the groups, six dropped out before the intervention (Figure 3). Out of 30 participants tested at baseline, 29 completed the posttests (24 females, 5 males). One person from the conventional training group dropped out after seven weeks due to other personal reasons not related to the study. One CrossFit® participant was excluded from the VO_{2peak} analysis due to measurement errors, and one conventional training participant was excluded from the work capacity analysis due to not being able to complete the pretest. Twenty-seven participants completed all 24 training sessions while two participants from the CrossFit® group completed 22 and 23 sessions, respectively. No adverse events were reported during the intervention.

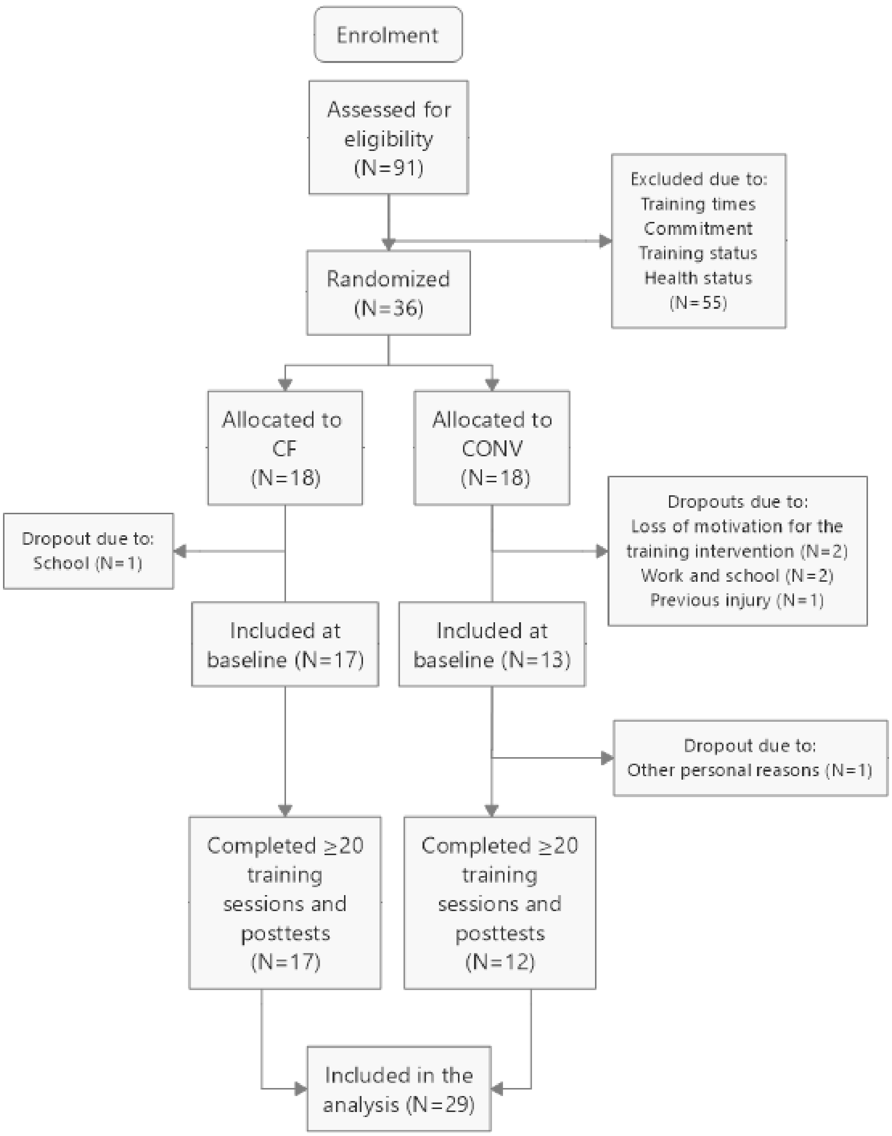

Figure 3: Flowchart. CF=CrossFit®, CONV=Conventional training.

The participants had a mean age, height and body mass of 23 years, 173 cm and 71.7 kg. The CrossFit® group seemed to have a higher VO_{2peak} and a lower body mass than the conventional training group at baseline, while the other parameters were similar (Table 4 and 5).

Table 4: Participants descriptive data. CF=CrossFit®. CONV= Conventional training.

	CrossFit® (N=17)	**Conventional training (N=12)**
Age (years)	23 ± 3	23 ± 2
Height (cm)	174 ± 7	172 ± 7
Body mass (kg)	68.7 ± 9.5	74.6 ± 18.3
Muscle mass (kg)	29.2 ± 5.8	29.0 ± 6.1
Fat mass (%)	23.7 ± 8.5	29.6 ± 8.2

Presented as mean data ± SD.

3.2. VO_{2peak}, Work capacity and Sprint performance

After eight weeks of CrossFit® and conventional training, there was a between group difference of 2.43 $mL*kg^{-1}*min^{-1}$ in VO_{2peak} favoring the conventional training group (CI:0.46-4.4, d=0.97, p=0.017). From pre- to posttest, the CrossFit® and conventional training group improved with -0.21 (CI:-1.6-1.2, p=0.75) and 2.22 (CI:0.72-3.7, p=0.008) $mL*kg^{-1}*min^{-1}$, respectively (Table 5, Figure 4).

A between group difference in work capacity favored the conventional training group with 0.38 min (CI:-0.72-1.5, d=0.27, p=0.49) and sprint performance favored the CrossFit® group with 0.23 sec (CI:-1.4-0.97, d=0.15, p=0.69). The between group differences were not significant. Within group analysis showed that work capacity improved by 2.4 min (CI:1.7-3.1, p<0.001) and 2.8 min (CI:1.8-3.7, p<0.001) in the CrossFit® and conventional training group, respectively. Sprint performance also improved with 1.5 sec (CI:0.62-2.4, p=0.002) and 1.3 sec (CI:0.42-2.1, p=0.007).

Table 5: Changes in VO_{2peak}, work capacity and sprint performance from pre- to posttest in the CrossFit® and conventional training group.

	CrossFit® (N=17)		**Conventional training (N=12)**	
	Pretest	Posttest	Pretest	Posttest
VO_{2peak} ($mL*kg^{-1}*min^{-1}$)	52.02 ± 8.31	51.81 ± 7.99	45.38 ± 7.65	47.60 ± 6.70**[a]
Work capacity (min)	10.3 ± 2.6	7.9 ± 2.0***	10.9 ± 3.2	8.2 ± 2.2***
Sprint (sec)	36.2 ± 5.7	34.7 ± 4.8**	36.4 ± 4.0	35.1 ± 3.4**

Data presented as mean ± SD. VO_{2peak} =peak oxygen uptake. Significant difference within groups from pre- to posttest, *p<0.05, ** p<0.01, *** p<0.001. [a]Significant difference between groups from pre- to posttest (p<0.05).

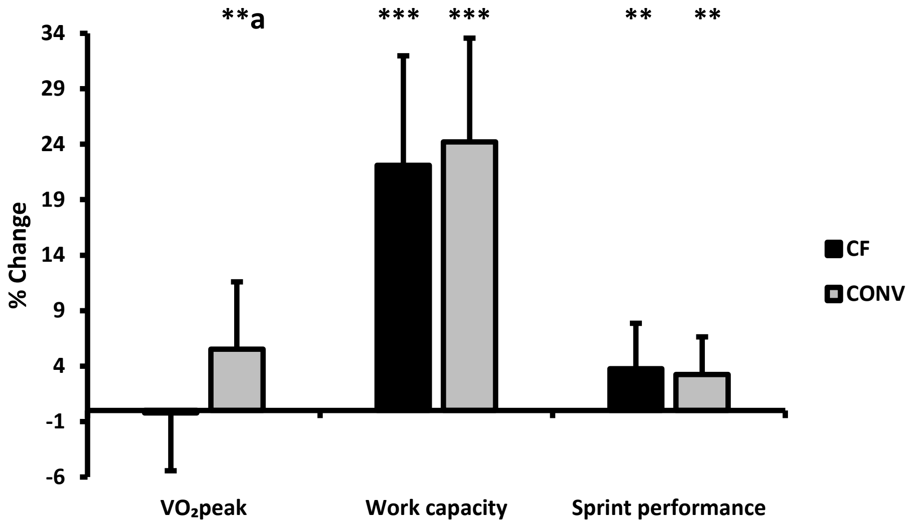

*Figure 4: Percentage change in VO_{2peak}, work capacity and sprint performance from pre- to posttest in the CrossFit® (CF) and Conventional training (CONV) group. Presented as mean ± SD. VO_{2peak}=peak oxygen uptake. Significant difference within groups from pre- to posttest, *p<0.05, **p<0.01, ***p<0.001.*
[a] Significant difference between groups from pre- to posttest (p<0.05).

3.3 Degree of satisfaction

To quantify the mental aspect of the training program, the participants answered a questionnaire at the beginning, mid-way and at the end of the intervention. Only question 1 (Table 3) about how satisfied the participants were with the training program, was significantly different between the groups (Q1: Intervention, Figure 5). For this question, participants in the CrossFit® and conventional training group gave a median score of 9 (IQR:1) and 8 (IQR:1) on the first session respectively (p=0.016), the same for the CrossFit® (IQR:1) and conventional training group (IQR:2) halfway in the intervention (p=0.007), and 10 (IQR:1) and 8.5 (IQR:2) on the last session (p=0.027).

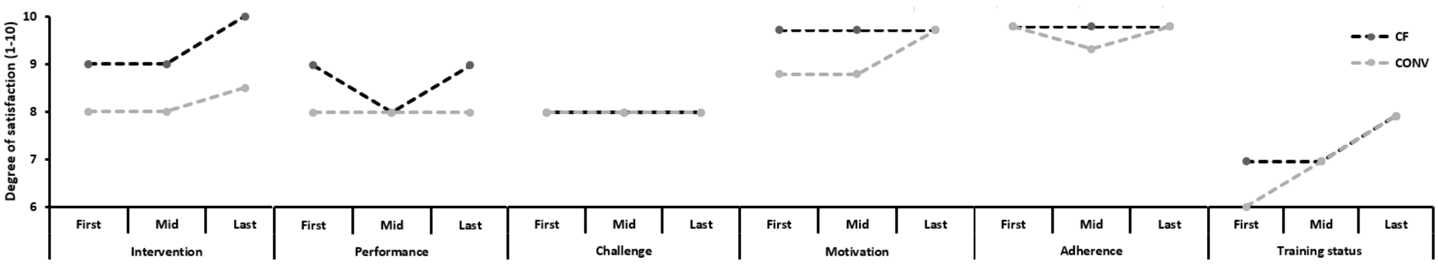

Figure 5: Degree of satisfaction (1-10) for question 1-6 the first, middle and last session for the CrossFit (CF) and Conventional training (CONV) group. Q1: intervention, Q2: performance, Q3: challenge, Q4: motivation, Q5: adherence, and Q6: training status.

4. Discussion

The main finding in this study was that eight weeks of conventional training led to a greater increase in VO_{2peak} compared to CrossFit®. Work capacity and sprint performance improved similarly in both groups. A higher degree of satisfaction for the training intervention was reported in CrossFit® participants, possibly due to the interest of exploring CrossFit® among the participants.

4.1. VO_{2peak}

VO_{2peak} increased significantly more in the conventional training group (5.5%) than in the CrossFit® group (-0.22%)(Figure 4), with a large effect size of 0.97. A larger improvement in the conventional training group was expected as HIIT is shown to yield great increases in VO_{2max} due to an increase in maximal cardiac output and thus from changes in maximal stroke volume (24, 26). These physiological effects will be affected by different forms of exercise with varying intensity, duration, repetitions and rest periods (15). Doing a variation of exercises in CrossFit® will possibly not trigger the aerobic system in the same way as HIIT, as the intensity and duration differ (often short in duration with little to no active recovery). The running specificity from doing HIIT constantly for eight weeks is demonstrated in the study by Carnes and Mahoney (17). The study showed that CrossFit® combined with HIIT improved less in VO_{2max} (3.4%) compared to long-distance running (8.5%), with less time spent running.

Since our CrossFit® group did not have any aerobic improvements, the complexity of the strength exercises could contribute to a reduced intensity on the workouts. However, CrossFit® is shown to be an effective form of concurrent training to increase endurance and muscular strength due to the use of strength exercises under metabolic stress (27). One study that compared HIIT with high intensity functional training found no differences in moderately trained participants in improved VO_{2max} after performing 3-4 sets of 8x20 sec with 10 sec rest with either running or functional exercises (28). CrossFit® cannot be generalized to other high intensity functional training programs as it often includes more technical exercises, but this study showed that functional exercises can yield similar improvements in VO_{2max} as HIIT when performed in the same exercise format.

Studies suggests separation of endurance and resistance training in different sessions for greatest improvements in endurance and strength (29, 30), and it could be discussed if the interference effect is smaller in conventional training compared to CrossFit® where the exercises often are interchangeable. This interference effect is unclear, but reviews on concurrent training (13, 31) found minimal negative effects on HIIT when combined with strength exercises. One study examined the aerobic effects on concurrent training after 12 weeks of training in active young males (32). The study showed that VO_{2max} improved more when HIIT was performed before strength training (13.7%), but also more than when aerobic training was performed alone. This could be explained by the peripheral adaptations in the muscles from the resistance training, allowing participants to exercise for longer time at a given submaximal speed (33). The HIIT program in this study consisted of shorter exercise bouts on a 200m track compared to our 4x3 min intervals. A similar study intervention conducted by Bahremand and colleagues (16) showed a greater improvement in VO_{2max} in both CrossFit® (36%) and concurrent training (26%) than the present study. The concurrent training group in the Bahremand study did moderate endurance training for 22.5 minutes compared to 25 minutes of HIIT in our conventional training group, so it is somewhat surprising that these participants had the level of improvement that they did. In that study, the concurrent training group started with endurance before resistance training every session, reducing the interference effect from resistance training. This could possibly cause a greater increase in VO_{2peak} compared to an alternating workout in our conventional training group.

To a certain degree, longer time in a high percentage of HR_{max} have been shown to give greater improvements in VO_{2peak} (24). Helgerud and Wang with colleagues (24, 26) found an improvement of 7.2% and 13% in VO_{2peak} respectively after eight weeks of 4x4 minutes HIIT (90-95% of HR_{max}). This is smaller improvements than our study, which could be due to shorter duration of the intervals (3 min) and an intensity of 85-95% of HR_{max} in our study. However, a slightly lower intensity in our study made it easier to regulate the intensity combined with resistance training. Heart rate was not measured during the CrossFit® workouts, and it is difficult to say which % of HR_{max} the CrossFit® participants had compared to the conventional training participants. An intensity of 90-95% of HR_{max} is found in some CrossFit® benchmark workouts, but this was in experienced CrossFitters and the intensity might not be that high in unexperienced participants (34). As the intensive aerobic part in our CrossFit® workouts varied in duration and combination of exercises, it is more difficult to constantly adjust the intensity (% of HR_{max}) compared to 4x3 min exercise bouts in HIIT.

Another explanation of the lack of improvement can be the high baseline values of 52.02 $mL*kg^{-1}*min^{-1}$ in the CrossFit® group compared to 45.38 $mL*kg^{-1}*min^{-1}$ in the conventional training group. This will give less capacity for improvements, as the greatest differences in VO_{2max} for beginners are noted during the first six months of training (35). Since more fit endurance athletes requires a higher training stimulus, a volume of three training sessions per week could be too low for an increase in aerobic capacity, especially when the focus in the workout is not only endurance. It is therefore important to consider the training status of the participants when comparing results. Some of our participants reported more than three training sessions per week prior to the Coronavirus outbreak (before the last six months prior to our study), and many reported an increase in endurance activities instead of resistance training during the Coronavirus outbreak. However, both groups seemed to have a similar training background in endurance and resistance training.

Other studies in physically active participants, unexperienced to CrossFit® (7, 16, 36) did find an improved VO_{2max}, but the participants had a lower baseline VO_{2max} than our study. The study by Bahremand and colleagues (16) had a baseline VO_{2max} of 45.8 and 42.5 $mL*kg^{-1}*min^{-1}$ for the CrossFit® and concurrent training group respectively. Barfield and Anderson (36) improved VO_{2max} with 6% in 25 physically active males with only two sessions per week. Their baseline VO_{2max} (41.5 $mL*kg^{-1}*min^{-1}$) were also lower than our group. Most of our participants were females, and since males 20-29 years have an average of 10 $mL*kg^{-1}*min^{-1}$ higher VO_{2max} than females at the same age and fitness level, this lower value could cause a further aerobic improvement (37). Similar to our study, Drake and Sobrero with colleagues (11, 12) found no improvements in six and eight recreationally active participants after four and six weeks of CrossFit®, respectively. The participants in Sobrero had a low baseline value (39.14 $mL*kg^{-1}*min^{-1}$), but the participants in Drake had a similar baseline value to our CrossFit® group (52.9 $mL*kg^{-1}*min^{-1}$). These studies had a small number of participants and a short training intervention, and the individual results will have a great influence on the average values. In addition, differences in the CrossFit® programming can explain the varied results from CrossFit® studies, as the workouts will have different intensities, exercises and exercise loads. Since the workouts are not standardized, it is difficult to compare our study with previous CrossFit® studies.

4.2. Work capacity

The conventional training group demonstrated similar improvement (24.2%) as the CrossFit® group (22.1%) in work capacity. The effect size (d=0.27) indicates a small effect. The CrossFit® workouts in our study included thrusters and burpees multiple times, and some of the sessions were in the same format of 21-15-9. Improvements for the CrossFit® participants will result from the specific adaptations from the applied stimuli (27), as well as a psychological impact where they have learned to push themselves in similar workouts. Even if most workouts did not include these exercises, the high intensity and varied functional exercises could prepare the participants for other workouts even if they are not specialized (38). Another explanation to these results could be an improved muscular endurance after doing many repetitions in the workouts (39). Due to many repetitions in the work capacity test, this could be an indirect measurement on muscular endurance. Our results in work capacity are similar to a 20% improvement in a study by Paine (38). This study included CrossFit® workouts 4-5 times per week over a six-week training period in 14 men and women with various CrossFit® experience. All four physical assessments in the study gave similar improvements in work capacity, indicating a consistent increase in performance across metabolic pathways and the 10 physical skills.

Even if the conventional training group did none of these exercises, they were able to improve their performance time. In the study by Menz and colleagues (28) burpee performance improved after both high intensity functional training and HIIT, with a larger improvement using functional exercises. It should also be mentioned that the conventional training participants had a greater increase in maximal strength for bench press and half squat than the CrossFit® group (21), which combined with a higher VO_{2peak} could improve work capacity. The work capacity test had an average performance time of 10.6 minutes and will use both the aerobic- and anaerobic system. Studies have found an association between CrossFit® performance in the same format of 21-15-9 and lower extremity muscular strength, aerobic- and anaerobic capacity (5, 9, 40). Even if a relationship is not investigated in our study, the results from the conventional training group could indicate that an improved VO_{2peak} and muscle strength could affect the CrossFit® performance. Since all participants were unfamiliar to CrossFit® exercises in our study, a new training stimuli in the test format 21-15-9 would likely cause positive adaptations in both groups for an increased work capacity (38).

4.3. Sprint performance

Sprint performance improved similarly with 3.8% and 3.2% in the CrossFit® and conventional training group, respectively, and the effect size was small (d=0.15). A greater improvement was expected in the CrossFit® group due to many explosive movements (e.g. Olympic weightlifting), which could lead to an increased rate of force development by decreasing ground contact time while running (41). The similar improvement in sprint performance in the conventional training group can be explained by a greater increase in maximal half squat strength (42), as anaerobic peak power is related to muscular strength (33, 43). CrossFit® exercises were usually combined with other exercises, which will decrease the intensity on each exercise compared to doing one exercise separately (i.e. 200m run). This could possibly trigger the anaerobic system in a similar way as the three-minutes intervals in the conventional training group. To my knowledge, this is the first study to assess the effect on sprint performance from CrossFit®. Most studies investigating anaerobic capacity in CrossFit® have used the Wingate anaerobic test on a cycle ergometer, assessing peak power (5, 7). Crawford found a significant difference with a mean change of 13.4% in peak power in 25 untrained adults after a six-week CrossFit® intervention (5). Our study showed that CrossFit® can be as effective as conventional training in improving a 200-m sprint performance.

4.4. Degree of satisfaction

The CrossFit® group reported a higher degree of satisfaction in the question about the training program, but the other questions were similar between the groups. Most people that showed interest in the study was curious about CrossFit® and wanted to try the training modality. Some participants dropped out before the training intervention due to randomization to the conventional training group. The training motivation was nevertheless similar for both groups, which could be explained by participants volunteering to this project. Since everyone trained in groups, it was not expected a great difference in degree of satisfaction between the groups. Corona was a situation in this period and the trainings were a social arena to meet others weekly, probably increasing degree of satisfaction for both groups. The social aspect in a group setting when exercising could be just as important as the training modality. The satisfaction with the training program in CrossFit® compared to conventional training can be supported by a study from Heinrich et al. (20). The study showed a higher adherence to the training program in CrossFit® compared to moderate-intensity aerobic and resistance training. Both groups maintained exercise enjoyment, but the CrossFit® group spent less time exercising (63 min compared to 13 min workout in CrossFit®). More time spent for the moderate training group could cause less adherence to the training program. In our study, the groups were time-matched for the total training time, but our CrossFit® group did also spend less time on the main workout than the conventional training group due to longer time used on the warm-up and technique training. As there are lacking studies comparing CrossFit® with conventional training on satisfaction, these studies suggests that the social and various training modality in CrossFit® could possibly make it easier to maintain the motivation and adherence to the training program over time. It should be noted that both groups reported a high degree of satisfaction with only one point difference on a 1-10 scale, so this needs to be verified.

Regarding the other questions in the questionnaire, there are some small differences throughout the intervention. The CrossFit® group reported a drop in own performance mid-way, which could be explained by the increase of more technical exercises after the first week. They also reported a flat increase in training status compared to a steep increase in the conventional training group. This subjective experience of an improved training status could reflect the improved physiological outcomes. It should be mentioned that this is only one way to perform CONV. Varying the strength exercises and the exercise bouts in HIIT can possibly induce a higher satisfaction with the training program in the conventional training group.

4.5 Strengths and Limitations

A strength in the study is the familiarization week before the pretests to reduce the learning effect from the exercises used in the tests. However, the learning effect could be a problem from pre- to posttest, even with the familiarization week. This will especially be apparent in the work capacity test, as they learn how to manage the load over a given time. Work capacity was only assessed using two exercises in the format 21-15-9, and the improvements could be different if other formats were used. Compared to other studies (9, 40), the exercises in the work capacity test were chosen so the participants did not need to adjust the load or the exercise. Standardizing the exercises is more comparable between the groups than scaling the test exercises individually because the exercises can be performed differently. Another strength is the high attendance from the participants, as only two participants did not complete all workouts. During the intervention, only one participant dropped out, and this was not related to the study.

The main limitation in this study was lack of blinding of the test leaders, training supervisors and participants due to practical reasons. Blinding of the participants was not possible due to study nature. To compensate for this, the participants trained at different times to reduce the impact on each other. Since there were a lot of different tests, we found it beneficial to perform the testing ourselves. By standardizing the verbal information and motivation during the testing and training, detection bias was reduced to not favorize any of the groups. As many other randomized controlled studies, this study included small intervention groups over a short time-period. A low statistical power and type II error could be apparent due to a low number of participants, and there could be significant effects that the research was not able to detect. The questionnaire about degree of satisfaction was not validated, and the subjective results should be interpreted with caution due to the possibility for a finding by chance. Since the participants trained in groups, the results cannot be generalized to individual training. Also, this study cannot be generalized to experienced athletes or the rest of the population due to a small sample size, age range and a motivation to try CrossFit®. A selection bias in the study is that the participants volunteered and could be more motivated for training. During the workouts, it was also easier to follow up the conventional training group as there were less participants per instructor, regarded as a performance bias.

5. Future research

Future studies about CrossFit® should include longer training interventions with more participants for an increased validity of the study. Longer duration will allow for a higher intensity as the technical skills will be improved at the beginning of the study. If a new CrossFit® study includes unexperienced participants, it could be helpful to exclude the most technical exercises (i.e. clean and jerk, kipping and handstand) to increase the intensity from the beginning of the intervention. A study by Cosgrove and colleagues (44) investigated the effect of long-term CrossFit® (6 months) in unexperienced (0-6 months experience) and experienced (7+ months experience) CrossFit® athletes, and found that the unexperienced participants increased more in aerobic capacity than the experienced. As this study had a longer duration of the intervention, the unexperienced participants had time to learn the technique, know which weights to use and know their own limits; possibly increasing their pain threshold (38). To measure the intensity, it could have been beneficial to use a heart rate monitor in the sessions. However, the exercises will have various effects on the heart rate, making it difficult to adjust the intensity based on the heart rate. If another study should be performed, recreationally active participants with CrossFit® knowledge (inclusion criteria to exercise ≤three times/week prior to study) could be beneficial, to better regulate the intensity of the workouts. Another solution is to include a longer familiarization week (e.g. 3-4 weeks). The little agreement in previous studies indicate that this is an area that needs to be investigated further, especially as CrossFit® is becoming increasingly popular. CrossFit® could probably become even more appealing if it is found to be effective in improving performance benefits, as many people want to adhere to a time-efficient training modality. The rest of the physical skills should also be investigated, to see if CrossFit® will improve in other parameters. It would especially be interesting to test upper and lower body muscular endurance directly (e.g. a muscular endurance bench press and squat test), as the workouts often have a lot of repetitions. More studies comparing CrossFit® with conventional training should be done to strengthen this research field.

6. Practical Implications

As this is the first study to compare CrossFit® with conventional training, this contributes to new knowledge about the performance benefits from CrossFit® in recreationally active men and women within the age 18-30 years. The results from this study indicate that conventional training is more effective in improving VO_{2peak} than CrossFit®. This could be of importance for CrossFit® athletes, people that want to know which training modality to choose for an increased VO_{2peak}, and for physical therapists and coaches who make training programs. It could be beneficial for CrossFit® athletes to supply with HIIT in separate sessions to optimize their aerobic endurance and thus their CrossFit® performance. There seems to be no difference between CrossFit® and conventional training for improved work capacity and sprint performance, which is important for the same group of people when planning a training program. Since both training modalities will cause similar improvements in these parameters, the training modality of most interest could be beneficial to use for a higher adherence to the training program. In this study, participants in the CrossFit® group reported somewhat higher satisfaction with the CrossFit® intervention, which potentially could lead to a higher adherence to training. However, these findings could at least partly be explained with curiosity to CrossFit® and the findings should be interpreted with caution. This study did not include all the physical skills which CrossFit® aims to improve.

7. Conclusion

The main finding in this study was that conventional training was more effective in improving VO_{2peak} than CrossFit® after eight weeks of training in recreationally active men and women. CrossFit® could be as effective as conventional training in improving work capacity and sprint performance. Both groups showed a high degree of satisfaction, but the CrossFit® group seemed to be more satisfied with the training program. This should be interpreted with caution due to selection bias, and the findings should be verified in a larger randomized controlled trial.

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Appendices

Appendix 1. Eligibility form

Generell informasjon	
Navn	
Fødselsdato	
Høyde (cm)	
Vekt (kg)	
Email	
Telefonnummer	
Har du skader eller andre helserelaterte utfordringer? hvis ja, utdyp.	
Treningsbakgrunn	
Hvor mange økter i uka har hatt de siste 6 mnd?	
Beskriv kort innholdet i disse øktene (varighet, type trening, intensitet, type øvelser etc., ca. antall sett og reps)	
På en skala fra 1-10, hvor motivert er du for trening? (1 = ikke motivert i det hele tatt, 10 = kunne ikke vært mer motivert)	

Jeg bekrefter at informasjonen over er korrekt og at jeg kan trenes basert på dette. Hvis min helsestatus eller treningsstatus endrer seg i løpet av studien er jeg pliktig å informere trenerne så fort som mulig.

Dato Signatur

Appendix 2. Informed consent

Har du lyst til å delta i masterprosjektet ''Effekten av CrossFit versus konvensjonell trening på maksimalt oksygenopptak, anaerob kapasitet, muskulær styrke, muskulær kraft, arbeidskapasitet og kroppssammensetning''?

Hensikten med studien

Du er invitert til å delta i et masterprosjekt i samarbeid med NTNU hvor formålet er å undersøke de fysiologiske effektene av CrossFit sammenlignet med konvensjonell styrke- og utholdenhetstrening. CrossFit er en gruppebasert treningsform som innebærer konstant varierte, funksjonelle bevegelser utført med høy intensitet. CrossFit-økter er dermed sjeldent like da ulike øvelser settes sammen på ulike måter for hver økt for å skape variasjon og uforutsigbarhet. Konvensjonell trening defineres som en form for mer tradisjonell trening hvor man trener styrketrening med frivekter og høyintensiv intervalltrening på tredemølle i samme økt. De konvensjonelle treningsøktene er like hver gang hvor målet er å øke belastningen (kilo/motstand og gjerne hastighet på intervalldragene) for å stimulere kroppen. For å kunne sammenligne effektene av de to ulike treningsmetodene (CrossFit og konvensjonell trening) vil fysiske tester bli gjennomført før og etter treningsperioden. Dette informasjonsskrivet vil gi mer informasjon om detaljene knyttet til studien og hva deltakelse vil innebære for deg.

Hvem er ansvarlig for studien?

Masterprosjektet vil bli gjennomført i samarbeid med NTNU (Norges tekniske naturvitenskapelige universitet) og er en del av den internasjonale mastergraden Physical Activity and Health ved det medisinske fakultet, institutt for nevrovitenskap og bevegelsesvitenskap.

Hvem kan delta i studien?

I studien ønsker vi å inkludere friske menn og kvinner i alderen 18-30 år som trener 1-3 ganger i uka. Deltakelse i idrett på lavt nivå er også tillat. Vi ønsker å rekruttere 30 deltakere og da du møter disse kriteriene inviterer vi deg til å delta i dette masterprosjektet.

Hva innebærer deltakelse?

Deltakelse i studiet innebærer 8 uker trening, 1 uke opplæring og 4 uker testing (2 uker før og 2 uker etter treningsperioden). Studieoppstart er 7. september og studien har en total varighet på 13 uker. Opplæringen vil bestå av totalt 3,5 timer fordelt over to dager. Testing vil bestå av totalt 6 timer fordelt over tre dager før treningsperioden og tre dager etter treningsperioden. Siste uke med testing og avsluttende uke av studien vil være 30. november – 6. desember. Treningsøktene og majoriteten av testene vil foregå på CrossFit Maxpuls Lade. Maksimalt oksygenopptak og kroppssammensetning vil testes på St. Olavs Hospital. Du som deltaker blir tilfeldig plassert i CrossFit-gruppen eller den konvensjonelle treningsgruppen. Disse gruppene deles igjen i to slik at det totalt er 4 treningsgrupper. I hver gruppe vil det være 7-8 deltakere som skal trene sammen hver mandag, onsdag og fredag gjennom den 8 ukers lange treningsperioden. Før og etter treningsperioden vil din fysiske form bli testet gjennom en rekke fysiske tester (disse testene er forklart i detalj i påfølgende avsnitt). Deltakelse i studien innebærer også at man ikke kan trene systematisk styrke og/eller utholdenhetstrening utenfor prosjektet.

Treningsintervensjon

Som deltaker i studien vil du bli randomisert (tilfeldig plassert) i CrossFit-gruppen eller den konvensjonelle gruppen (tradisjonell styrke- og utholdenhetstrening). Det vil si at du ikke kan velge treningsform selv. CrossFit-gruppen kommer til å trene 24 ulike økter i løpet av de 8 ukene. Den konvensjonelle treningsgruppen kommer til å trene det samme hver økt: 4x3-intervaller på tredemølle (fire treminuttersdrag) og styrkeøvelsene knebøy, benkpress og stående roing.

Hvilke tester skal gjennomføres?

Maksimalt oksygenopptak (Vo2maks) refererer til den maksimale mengden oksygen kroppen din klarer å ta opp og er ansett som det beste målet på kondisjon. Vo2maks måles ved å utføre en maksimal løpetest på tredemølle med oksygenmaske. Belastningen i form av hastighet eller stigning øker hvert minutt til man når utmattelse eller til andre tegn tilsier at man skal avslutte testen. Hvis du skulle oppleve et overveldende ubehag før dette har du mulighet til å stoppe testen når du måtte ønske. Målet med testen er å gå eller løpe til man ikke klarer å fortsette lengre grunnet utmattelse.

Muskulær kraft testes ved utføre et stille lengdehopp hvor målet er å hoppe så langt som mulig, og ved å kaste en medisinball så langt som mulig i stående posisjon.

Maksimal muskulær styrke referer til den største kraften en muskel eller muskelgruppe kan utvikle i en bevegelse. Dette måles ved å utføre en 1-repetisjon-maksimum (1RM) test i knebøy med stang og benkpress. 1RM er den maksimale vekta man klarer å løfte én gang.

Kroppssammensetning vil måles ved bruk av en analysemaskin og kroppsvekt i kilogram, andel fettmasse og andel muskelmasse vil bli registrert.

Anaerob kapasitet (hurtighet) vil testes ved å utføre en 200 m sprint.

Arbeidskapasitet vil bli testet ved å gjennomføre en treningsøkt bestående av tre runder thrusters og burpees med synkende repetisjoner hvor målet er å fullføre på kortest mulig tid.

Et spørreskjema knyttet til grad av tilfredshet vil også fylles ut tre ganger i løpet av studieforløpet: ved start, midtveis og ved slutten av de 8 ukene.

Smittevernstiltak

All trening og testing vil gjennomføres i henhold til smittevernsanbefalingene. Dersom du som deltaker skulle oppleve symptomer som feber, sår hals, hoste, pustevansker og muskelsmerter skal du ikke møte opp for trening og/eller testing. Ta kontakt med en av masterstudentene så fort som mulig dersom dette skulle forekomme (listet under kontaktinformasjon).

Risiko og ubehag

Du kan oppleve noe ubehag knyttet til Vo2maks-testen da det er en test som presser deg til du har nådd maksimal kapasitet. Til tross for dette er det en helt trygg og normal reaksjon på en slik test. All trening og testing i denne studien gjennomføres på en trygg måte og vil bli veiledet av kvalifisert personell for å sørge for at du som deltaker er komfortabel til enhver tid. Styrketrening kan også potensielt føre til forbigående ubehag og/eller muskelstivhet. All trening kan medføre en moderat risiko for muskel- og seneskade, men det er godt dokumentert at fordelene knyttet til å være fysisk aktiv veier opp for denne risikoen. Skulle du likevel oppleve økt smerte under trening eller utførelsen av en øvelse vil en 4-stegs tilnærming utføres: 1) redusere vekt/motstand i øvelsen, 2) redusere bevegelseshastigheten, 3) redusere bevegelsesutslaget og 4) unngå å utføre den spesifikke bevegelsen i minst én uke.

Potensielle fordeler ved å delta i studiet

Deltakelse i denne studien gir deg 8 uker gratis veiledet trening av kvalifiserte trenere samt gratis fysiologisk testing som gir en verdifull indikator på din fysiske form. Du vil potensielt lære mye om generelle treningsprinsipper da du vil få en detaljert opplæring i treningsteknikk og utførelse. Andre potensielle fordeler knyttet til deltakelse er økt Vo2maks, økt muskulær kraft og styrke, økt hurtighet, forbedret kroppssammensetning og økt arbeidskapasitet.

Samtykkefrihet

Du har rett til å trekke deg fra studiet når som helst uten å måtte oppgi en grunn. Vær vennlig å kontakte en masterstudentene listet under «kontaktinformasjon» hvis du bestemmer deg for å trekke deg fra studien før den er ferdig. Hvis du velger å fortelle de prosjektansvarlige hvorfor du forlater studien vil grunnen potensielt oppbevares som en del av prosjekts datamateriale. Informasjonen om deg som deltaker vil oppbevares og inkluderes i dataanalysen med mindre du ber oss om å fjerne informasjonen fra våre arkiver. Hvis de prosjektansvarlige allerede har brukt informasjonen om deg i dataanalyser vil det ikke være mulig å fjerne denne informasjonen i ettertid.

Personvern

Informasjonen om deg som registreres vil være navn, adresse, telefonnummer, epost, fødselsdato, vekt, høyde og treningsbakgrunn. Fysiske tester vil utføres for å kartlegge fysisk kapasitet. Disse dataene og informasjonen som registreres på deg vil bare brukes som beskrevet i henhold til formålet med denne studien. All informasjon og testresultater vil behandles uten navn og fødselsdato eller annen direkte gjenkjennbar informasjon. Et id-nummer kobler deg og informasjonen din til testresultatene via en navneliste. Dette betyr at informasjonen om deg er deidentifisert. Bare autorisert personell knyttet til masterprosjektet vil ha tilgang til navnelisten og kan koble informasjonen til deg. Det vil ikke være mulig å identifisere deg i studiens resultater når den er publisert. Til kontrollformål vil data uten personlig informasjon trygt oppbevares på en harddisk hos NTNU til 15.06.2026. Etter denne datoen vil disse dataene bli slettet. Byråer som muligens kan kontrollere datamaterialet er eksempelvis forskningsansvarlig eller etiske komiteer.

Deltakers rettigheter

Som deltaker har du rett til å be om tilgang til personlig data, inkludert sletting, retting eller begrensning av data. Dette inkluderer også dataportabilitet som tillater deg å få og bruke personlig data til egne formål. Du har også rett til å sende en klage til personvernombudet hos NTNU eller norsk senter for forskningsdata hvis ønskelig (listet under kontaktinformasjon).

Forsikring

Som universitet er NTNU selvforsikret og ansvarlig for å forsikre at det vi gjør er i samsvar med lover og regler til enhver tid. Dette betyr at når et prosjekt er godkjent hos NTNU er NTNU ansvarlig for forsikring om en deltaker skulle bli skadet på grunnlag av det vi ber dem om å gjøre.

Informasjon om utfallet av studiet

Som deltaker i denne studien har du rett til å få informasjon om studiens resultater. Du vil få tilgang til denne informasjonen etter at resultatene er publisert.

Kontaktinformasjon

Ved spørsmål relatert til deltakelse eller ønske om å ta i bruk dine rettigheter som deltaker, ta kontakt med en av personene listet her:

Masterstudent: Rebekka Resell Mauring (+47 41 46 75 16, rebekkrm@stud.ntnu.no)

Masterstudent: Ingrid Bårtvedt (+47 92 80 20 96, ingridtb@stud.ntnu.no)

Veileder: Vegard Moe Iversen (+47 95 91 61 88, vegard.m.i@ntnu.no)

Personvernombud: Thomas Helgesen (personvernombud@ntnu.no)

NSD – Norsk senter for forskningsdata AS (55 58 21 17, personverntjenester@nsd.no)

Med vennlig hilsen,

Masterstudentene Ingrid Bårtvedt & Rebekka Resell Mauring

Samtykkeerklæring

Jeg har lest informasjonen i dette skrivet om masterprosjektet «CrossFit vs. konvensjonell trening» og forstår hva deltakelse innebærer for meg, samt potensiell risiko og ubehag deltakelse kan medføre. Tatt i betraktning disse opplysningene relatert til deltakelse samt at spørsmål jeg har hatt har blitt tilfredsstillende besvart, sier jeg meg villig til å delta i studiet på følgende grunnlag:

- ☐ Deltakelse i en 8 ukers treningsintervensjon, randomisert til enten CrossFit eller konvensjonell trening samt én opplæringsuke.
- ☐ Deltakelse i totalt 4 uker testing av maksimalt oksygenopptak, stille lengdehopp, medisinballkast, 1RM test i knebøy og benkpress, 200 m sprint, analyse av kroppssammensetning, arbeidskapasitet, og spørreskjema om grad av tilfredshet
- ☐ Deidentifisert informasjon om meg kan bli publisert
- ☐ Personlig informasjon om meg lagres og oppbevares hos NTNU i 5 år etter prosjektslutt

Jeg samtykker til at informasjonen om meg kan prosesseres til prosjektet er fullført.

Dato: Signatur:

Appendix 3. Familiarization week

The exercises used in the familiarization week for the CrossFit® and conventional training group are presented in Table A1 and A2.

Table A1: Exercises learned in the familiarization week for the CrossFit® group.

Day 1: 1.5 hours		Day 2: 2 hours	
Exercise	**Time**	**Exercise**	**Time**
Air squats - Normal - Squat to medicine ball - Normal	12 min	Deadlift - With medicine ball - PVC pipe - Barbell	25 min
Front squat - Medicine ball - PVC pipe - Barbell	18 min	Clean practice - Ground to overhead - Medicine ball deadlift and front squat - Sumo deadlift high pull - Hang power clean	45 min
Presses - Strict press - Push press - Push jerk - All combined	20 min	Push-ups - On the floor - Hands on a box	10 min
Thrusters	10 min	Pull-ups and ring rows	5 min
Wall balls	10 min	Barbell back squat	15 min
Rowing	15 min	Barbell bench press	15 min
Burpees	5 min		

Table A2: Exercises learned in the familiarization week for the conventional training group.

Day 1: 1.5 hours		Day 2: 2 hours	
Exercise	**Time**	**Exercise**	**Time**
Air squats - Normal - Squat to medicine ball - Back squat with PVC pipe	30 min	Treadmill	10 min
Front squat - Medicine ball - PVC pipe - Barbell	15 min	Barbell back squat - Build some weights	40 min
Presses - Strict press - Push press - Combined	20 min	Barbell bench press	30 min
Thrusters	10 min	Standing bent over row	30 min
Burpees	5 min		
Treadmill	5 min		
Stretching	5 min		

Appendix 4. CrossFit® elements and associated exercises

Table A3 shows the exercises used in the CrossFit® programming within the three elements metabolic conditioning, weightlifting and gymnastics. These are illustrated in Figure A1-A3.

Table A3: The three elements in CrossFit® and the associated exercises used in the training intervention.

Elements	Exercises
Metabolic conditioning	Run Row Assault bike Burpees
Weightlifting	Deadlift Clean and jerk Kettlebell swing Thrusters Wall balls Ground to overhead Dumbbell presses Front squat Push press
Gymnastics	Air squat Pull-ups Push-ups Sit-ups Box jump Lunges Kipping Toes to bar Ring rows Handstand Burpee box jump over

Figure A1: The metabolic conditioning apparatus assault bike. Photo: Anders Holmberg.

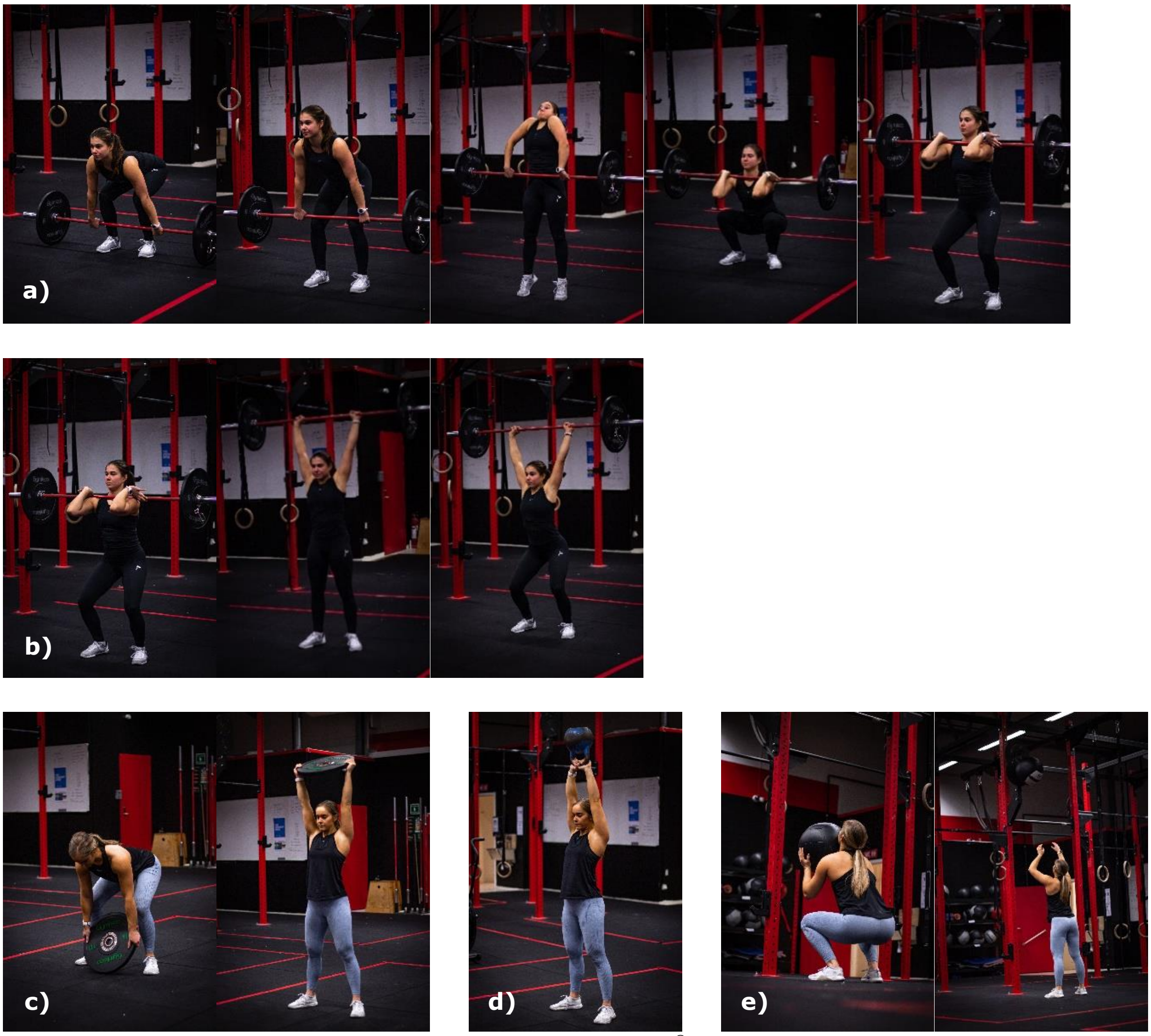

Figure A2: Example of weightlifting exercises used in the CrossFit® programming. a) variations of cleans; squat clean, hang squat clean, power clean, hang power clean, b) variations of presses; push press, strict press and push jerk, c) ground to overhead, d) kettlebell swing, and e) wall balls. Photo: Anders Holmberg.

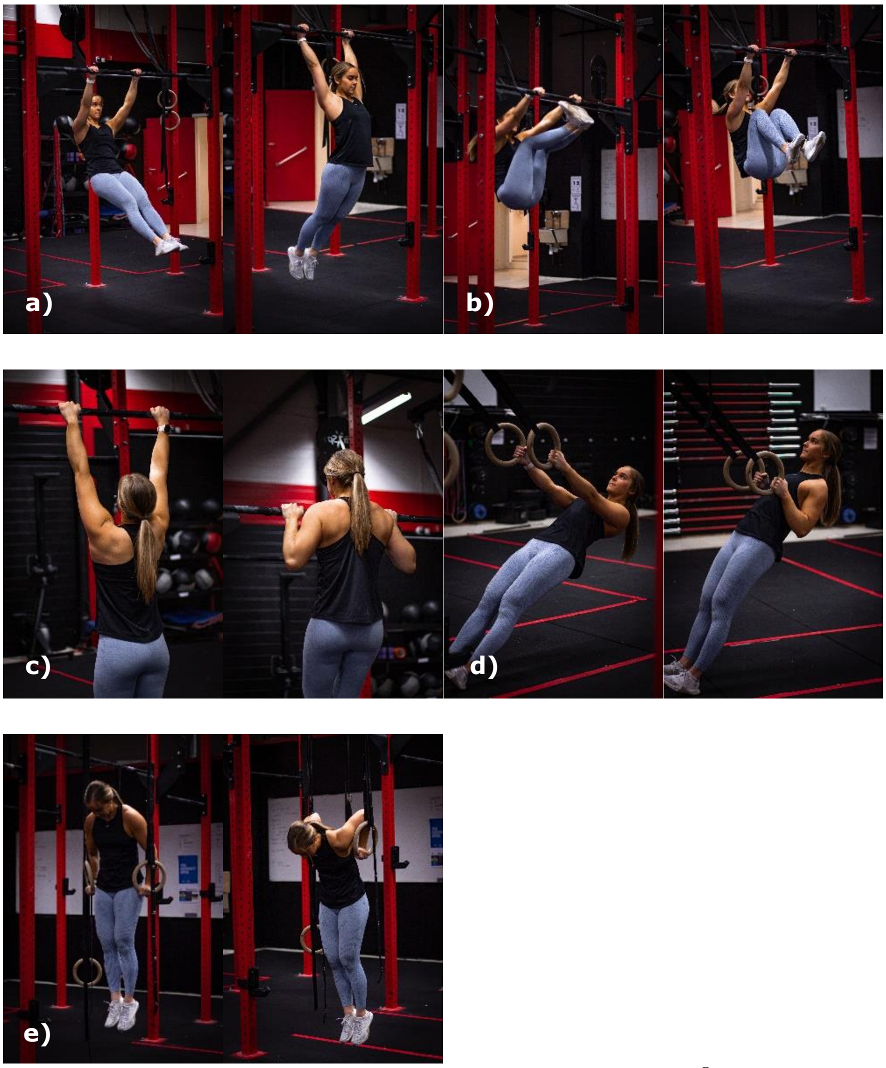

Figure A3: Example of gymnastic movements used in the CrossFit® programming. a) kipping, b) toes to bar/knees to chest, c) pull ups, d) ring rows, and e) ring dips. Photo: Anders Holmberg.

Appendix 5. CrossFit® warm-up exercises

Table A4 includes the warm-up exercises used in the CrossFit® intervention. Figure A4 shows an illustration of the main warm-up exercises used in the training intervention and in the work capacity test.

Table A4: Warm-up exercises for the CrossFit® group.

General warm-up	Barbell warm-up	Stretching
Air squats	5 Deadlifts	Active samson
Lunges	5 Good mornings	Active spiderman
Glute bridges	5 Elbow rotations	Childs pose
Climb outs w/pushups	5 Back squats	Hip stretch
Mountain climbers	5 Shoulder presses	Wall stretch
PVC pass throughs	5 Front squats	Pidgeon stretch
Sit-ups		Ankle stretch
Run/row/assault bike		Squat to stand
Pull down with band		Front rack stretch
Pull apart with band		
Hollow and arch hold		

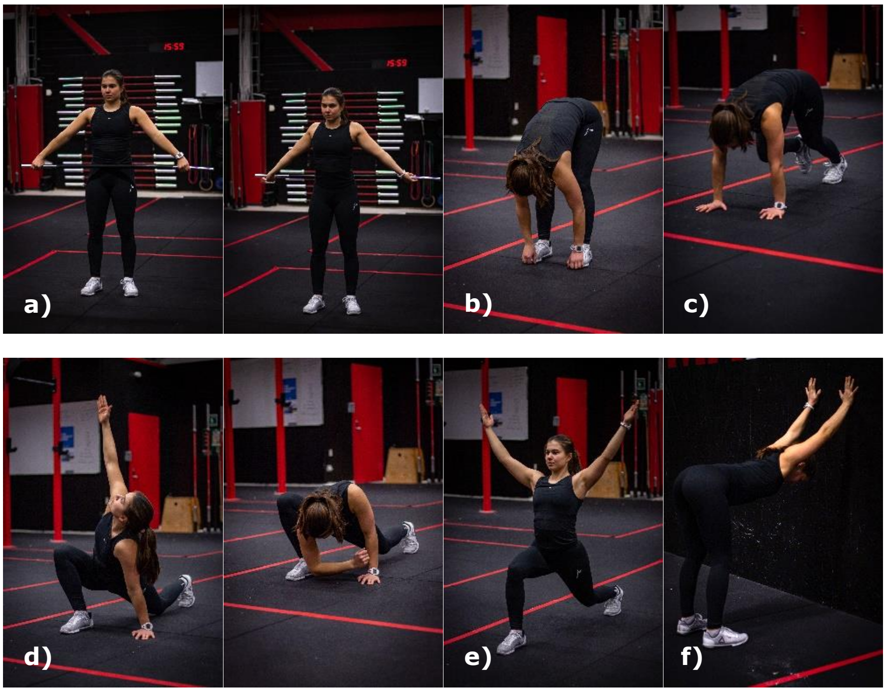

Figure A4: Example of the warm-up exercises used in the CrossFit® intervention and the work capacity test. a) PVC pass through, b) squat to stand, c) mountain climbers, d) active spiderman, e) active samson, and f) wall stretch. Photo: Anders Holmberg.

Appendix 6. Example of an interval from the conventional training

The participants in the conventional training group used a heart rate monitor every training session to regulate their intensity. A presentation of the heart rate indicated time in different % of maximal heart rate (Figure A5). This participant had a maximal heart rate of 195 bpm.

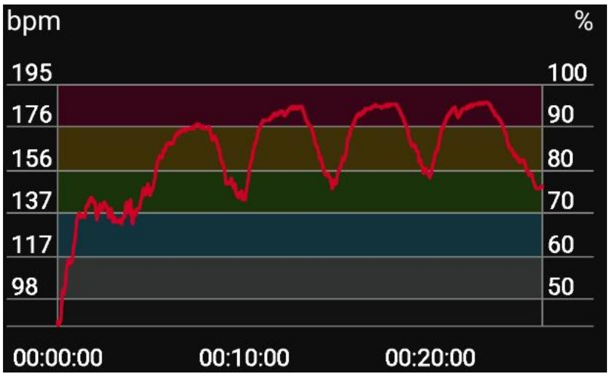

Figure A5: An example from one participant during an 4x3 minute interval using a heart rate monitor. Bpm=beats per minute. The different colors present the five different heart rate zones. Maximal heart rate of the participant was 195 bpm.

Appendix 7. Borg scale

Borg scale with rating of perceived exertion is presented in Figure A6, used in the maximal oxygen consumption test and work capacity test.

1 – 10 Borg Rating of Perceived Exertion Scale	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really Hard
10	Maximal: just like my hardest race

Figure A6: Borg scale from 1-10 with rating of perceived exertion.

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