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StartXFit—Nine Months of CrossFit® Intervention Enhance Cardiorespiratory Fitness and Well-Being in CrossFit Beginners

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Abstract: Insufficient physical activity (PA) is associated with low cardiorespiratory fitness, which favors cardiovascular and other noncommunicable diseases. Additionally, it evidentially affects mental health. Considering the WHO PA guidelines, CrossFit® represents a versatile exercise program that combines aerobic and resistance training with mobility and could help reduce disease incidences among sedentary people. Yet, long-term CrossFit research is sparse. We conducted a nine-month intervention (≥2 CrossFit workouts/week) in 16 beginners (14 males, 35 ± 6.8 years, 180 ± 8.6 cm, 85. 5 ± 19.1 kg). As a primary endpoint, VO_2max was assessed at baseline, four, and nine months. A repeated-measures ANOVA and Pearson correlation were conducted. Well-being was investigated by the WHO-5 Index pre- and post-intervention. For exploratory purposes, body composition and heart rate recovery (HRR) were tracked. In a second step, all males were categorized into two groups based on body fat percentage and analyzed by repeated measures ANOVA again. The main outcome was an 11.5% VO_2max improvement with a large effect ($p < 0.01$, $\eta_p^2 = 0.27$). Strong negative correlations between baseline VO_2max and its progression after nine months ($p = 0.006$, $r = -0.654$) were found. Well-being increased by 8.7% ($p = 0.024$, $d = 0.51$). HRR improved both at 1 min ($p < 0.05$, $\eta_p^2 = 0.34$) and at 5 min ($p < 0.05$, $\eta_p^2 = 0.27$) post-exercise. Resting metabolic rate increased by 2.2% ($p = 0.042$). Analysis by group revealed improved HRR at 1 min ($p < 0.05$, $\eta_p^2 = 0.62$) only for the "high body fat" group. This study reveals the potential of CrossFit to enhance physiological and psychological health in beginners. For more robust results, larger sample sizes with a higher proportion of women are needed.

Keywords: CrossFit; functional fitness training; group training; cardiorespiratory fitness; VO_2max; well-being; body composition; sitting hours

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1. Introduction

Despite the well-known adverse effects of sedentary behavior, regular engagement in physical activity (PA) decreases among populations worldwide. Especially in Western high-income countries, the number of people lacking regular PA grew from 30.9% in 2001 to 36.8% in 2016 [1]. Half of the employed men and women in Germany reported to be mostly sitting during their daily work in 2018 [2]. The COVID-19 pandemic supposedly worsened the situation, as it required social distancing and changes in daily activities. Recent studies reported negative effects of the pandemic on PA levels, hours spent sitting, and eating habits [3,4].

Health implications of sedentary behavior include increased risk of all-cause mortality, cardiovascular disease (CVD), adiposity, type-2 diabetes, cancer, and musculoskeletal disorders, as well as diverse mental and psychological illnesses [5–8]. CVDs must be mentioned in particular, as they account for almost one-third of all global deaths. Cardiorespiratory fitness (CRF), commonly measured as VO_2max, is an important clinical parameter to assess CVD risk. Low CRF is associated with reduced survival and higher incidences of CVD and other comorbidities [9]. It can be improved by a variety of endurance but also resistance training [10]. Evidence suggests that 5–10 min of running per day can reduce CVD risk and mortality [11]. The benefits of resistance training on CRF were also proven across different age groups [12]. Next to CRF, heart rate recovery (HRR) is considered a strong predictor of health outcomes, particularly with regard to cardiovascular disease risk [13]. HRR is divided into two phases: the early (fast) and late (slow) recovery phase [14]. The early phase describes the first minute after exercise cessation, whereas the late phase represents the time between minute 2 and the return to resting HR values. In general, endurance-trained individuals show faster HRR in comparison to untrained counterparts [15–17].

The WHO guidelines for PA among adults recommend both regular aerobic physical exercise as well as muscle-strengthening exercises [5]. A sport that targets this combination of stimuli in a time-efficient manner is CrossFit® (CF) (CrossFit® Inc., Washington, DC, USA). What is special about CF is the combination of routines from gymnastics, body weight exercises, and Olympic weightlifting in a group-based setting. It prepares athletes for diverse and random physical challenges [18] and was initially invented to cover the physical demands of people working in the military, police, or firefighting. For the general public, CF is still a new exercise modality. Even though previous research has investigated different physiological mechanisms that CF triggers, research especially on the long-term effects of CF training is yet sparse.

Previously reported effects of CF training on CRF are contradictory. McKenzie et al. found no significant VO_2max improvement in females after four weeks of intervention [19]. Inconsistent with this, Cosgrove et al. indicated that only female novices significantly improved throughout the six-month intervention, while males did not [20]. Likewise, Murawska-Cialowicz and colleagues found a significant VO_2max increase in women but not men [21]. Among studies investigating CF and body composition, the same ambiguity is found. Some report beneficial effects [21,22], whereas others found no effect [23]. One previous study investigated prolonged CF practice and overall well-being with no significant improvements [24].

Yet, several points are striking about previous CF literature. Many studies investigated short-term interventions or single CF training sessions [19,25–30]. Moreover, most studies included predominantly male subjects with CF experience [22,31]. Beneficial health outcomes could, however, be especially prominent in sedentary individuals without CF experience. Therefore, this target group needs further investigation. Exclusively, one six-month interventional study included male and female inactive employees. They identified beneficial outcomes on mobility and strength [24]. Following up on this, we aimed to fill the gap on continuous CF training and CRF in a sedentary population of CF beginners.

To the best of our knowledge, this is the first study to test the effects of a nine-month intervention in male and female working-age beginners with less than six months CF experience. This should control for interference with any previously existing CF-related fitness. Next to changes in aerobic capacity (VO_2max) and well-being, we investigated body composition and heart rate recovery (HRR) on multiple occasions. We anticipated that the high intensity and power output of CF training would provide a great stimulus for CRF and body composition improvement. Furthermore, frequent group workouts were thought to positively influence overall well-being.

2. Materials and Methods

In this pre–post, single-group, interventional study, participants engaged in regular CF training for nine months. We investigated CRF, well-being, body composition, and HRR during five screening visits at the laboratory. Three "big" measurements, including cardiopulmonary exercise testing (CPET) and anthropometric measures, were conducted after recruitment (t0), in months 3–4 (t2) and in months 8–9 (t4). In between, two "small" measurements (t1, t3) tracked the anthropometric measures. Pre- and post-intervention (t0, t4), participants filled in the WHO-5 Index for well-being. A study timeline is displayed in Figure 1. The study duration from August 2018 to September 2020 was because our participants did not all start at the same time but were recruited over a time course of 12 months and started the 9-month intervention subsequently.

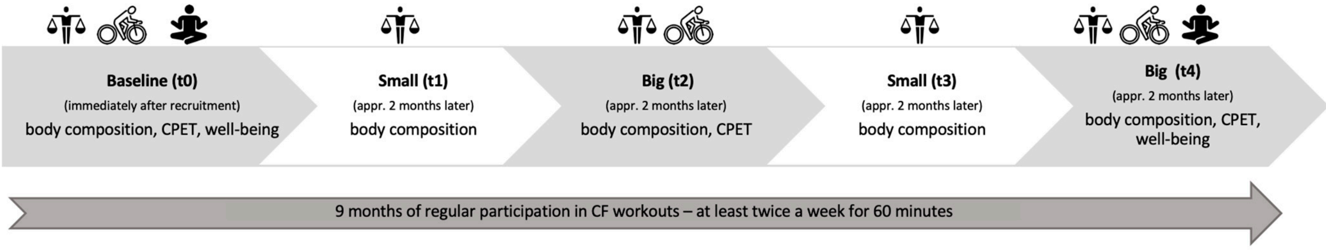

Figure 1. Study protocol with five screening visits (t0–t4) along the 9-month intervention timeline.

Subjects provided health-related information (smoker/nonsmoker, diet, history of disease and injuries, activity level at occupation) and reported their present and past participation in sports (CF and others).

This study was conducted in accordance with the 1975 Declaration of Helsinki and approved by the Ethics Committee of the University of the Bundeswehr Munich, Germany (6 April 2018). All participants provided informed consent before study participation. The trial was registered on ClinicalTrials.gov (trial number: DRKS00027059, accessed on 11 April 2021).

2.1. Subjects

Recruitment was conducted by use of advertising posters in nine CF affiliates in Munich (August 2018–October 2019). We included participants who were (1) aged 18 or older, (2) CF beginners (<6 months experience), (3) willing to perform $\geq$2 CF workouts/week for nine months, and (4) willing to attend five screening visits. Pregnancy and chronic or acute health issues (severe cardiovascular, respiratory, musculoskeletal, or metabolic diseases, osteoporosis, intervertebral disc damage, joint replacements, fresh scars, and hypertension) were defined as exclusion criteria. Forty-six participants were initially recruited for baseline screening (Table A1, supplement). Participants who missed screening visits were excluded from the analysis. All were informed about potential risks and advised to consult their physician before study participation. Afterwards, all provided written, informed consent.

2.2. Procedures

CF workouts combine multiple domains: Aerobic exercises (like running, cycling, or rowing), gymnastics and body weight movements (like handstands and pull-ups), and weightlifting routines (like squats, deadlifts, cleans, snatches, and overhead presses). A classical CF workout session comprises 60 min, starting with a warm-up and a skill development part. The "Workout of the day" (WOD) of about 10–20 min follows. The workout is summed up by a cool down. For more information on the sport, see Appendix A.1. The StartXFit protocol scheduled participation in $\geq$2 CF sessions per week for nine months. Both exercising with a coach and self-organized exercise ("open gym") in line with the CF concept were possible. Information on frequency and kind of CF participation during the study period was provided by the subjects in a questionnaire.

2.3. Endpoints

The primary endpoint was defined as the change in maximum oxygen uptake (VO_2max, in mL/min/kg) assessed by cardiopulmonary exercise testing (CPET). It was screened on three occasions, t0, t2 and t4. Statistical power analysis was based on the measurement of our primary endpoint. Development of psychological well-being was screened as a secondary endpoint with a questionnaire (t0 and t4). For exploratory purposes, body composition, maximum HR and HRR, and maximum power output on the bike ergometer were assessed at t0–t4. All physiological measures were performed at CrossFit Wuid in Munich at a standardized time of day (late afternoon).

2.4. Cardiopulmonary Exercise Testing (CPET)

For CPET measures, participants were instructed not to engage in vigorous exercise and to avoid alcohol or massive caffeine consumption 24 h before testing. They were advised to eat well three hours before and ensure adequate fluid intake. Maximum oxygen uptake (VO_2max, mL/min/kg) was assessed with a mobile breath-by-breath spiroergometry system (dynostics, Sicada GmbH, Bad Wörishofen, Germany). Subjects performed an incremental step test on an electronically braked cycle ergometer (motion cycle 800, emotion fitness GmbH & Co. KG, Speyer, Germany). The test was initiated with a load of 75/50 watts for males and females, respectively. A power increment of 25 watts/20 watts was applied every two minutes. Participants pedaled at 60–80 rpm. The test was conducted until maximal exertion, defined as fulfilling one or more of the following: RER of >1.1, VO_2 plateau, or heart rate within 10 bpm of age-predicted max. VO_2max was captured by averaging the VO_2 (mL/min/kg) of the last thirty seconds at individual peak performance. Heart rate was continuously tracked by use of a Bluetooth heart rate belt (Polar H9, Polar AG, Kempele, Finland). Heart rate recovery (HRR) was checked at (1) 1 min post- and (2) 5 min post-exercise cessation, representing the immediate and slow response in heart rate recovery, respectively.

2.5. Well-Being

The German version of the WHO-5 Index was used to test well-being. It is a well-respected method to assess psychological well-being, showing high validity and reliability [32]. The questionnaire comprises five simple statements on current mental health within the last two weeks. Participants rated their accordance with the statements on a 0–5-point scale, with 5 points representing the highest rank. All scores were summed up and multiplied by four. The resulting well-being score was given as a percentage, whereby 100% was achieved by rating all five statements with five points.

2.6. Body Composition

Anthropometric measures comprised height (cm), weight (kg), BMI (kg/m^2), muscle mass (%), body fat (%), and resting metabolic rate (kcal). Height was measured with the Seca 216 stadiometer (Seca, Hamburg, Germany). Body composition analysis was conducted by bioelectrical impedance analysis on a Tanita scale (Tanita SC-240 MA, Tanita Europe BV, Amsterdam, The Netherlands). Participants were measured with bare feet and wore either only shorts (males) or shorts and a sports bra (females). We advised participants to avoid changes in their nutritional habits 48 h before testing and ensure adequate hydration status.

2.7. Statistical Analysis

Prior to analysis, the raw breath-by breath spiroergometry data were screened for outliers. As no profound outliers were present, the raw data were analyzed without applying any rolling averages or other kind of smoothing. As a primary endpoint, the change in VO_2max between t0, t2, and t4 should display the effects of the CF intervention. For exploratory purposes, changes in body composition, maximum HR, HRR and maximum power output from t0 to t4 were assessed. Therefore, in a first step, we conducted a one-way repeated measures ANOVA for the whole group of male and female participants. To determine the most prominent change in VO_2max and all exploratory variables, post hoc Bonferroni-adjusted pairwise comparisons were subsequently performed. For a deeper analysis of the change in VO_2max, we performed a Pearson product-moment correlation between VO_2max at baseline (t0) and after nine months (t4) (ΔVO_2max mL/min/kg %) for the whole group of males and females. For this purpose, we divided the sample into three different groups (nonresponder, responder+, and responder++).

As the whole group showed an extremely uneven distribution of the sexes, in a second step, we conducted a more generalizable analysis by sorting out the only two female participants. The group of males was then categorized by body composition at baseline (t0), based on body fat percentage and BMI. The one-way repeated measures ANOVA with Bonferroni post hoc test was then repeated for the male sample categorized by group ("high body fat" and "low body fat"). All ANOVA results are shown as mean and 95% confidence interval (CI). Effect sizes are given as partial eta^2 (η_p^2) and interpreted as follows: small effect (>0.01), medium effect (>0.06), and large effect (>0.14). Cohen's d is indicated for the effect size and interpreted as follows: small effect (=0.2), medium effect (=0.5), and large effect (=0.8) [33].

A *t*-test for dependent samples was used to assess changes in the secondary endpoint well-being (t0–t4) for the whole sample [33]. All data were priorly analyzed for normality by the Shapiro-Wilk Test. In case of violations of normality ($p < 0.05$), we analyzed by the Friedman Test in addition to the parametric test. In case of violations of sphericity, tested by the Mauchly-test, a Greenhouse-Geisser adjustment was used. Statistical significance was set at $p \leq 0.05$. Descriptive statistics are presented as mean ± standard deviation (SD). All data analysis was performed in SPSS 28® (IBM SPSS, Armonk, NY, USA). For information on the power calculation, see Appendix A.2.

3. Results

Four of the 46 initially recruited participants were excluded (>six months of CF experience). Of the remaining 42 subjects, 16 completed the study protocol and provided enough data for inclusion in our analysis. This results in a dropout of 65.2%. Figure 2 displays the flow of participants throughout the study.

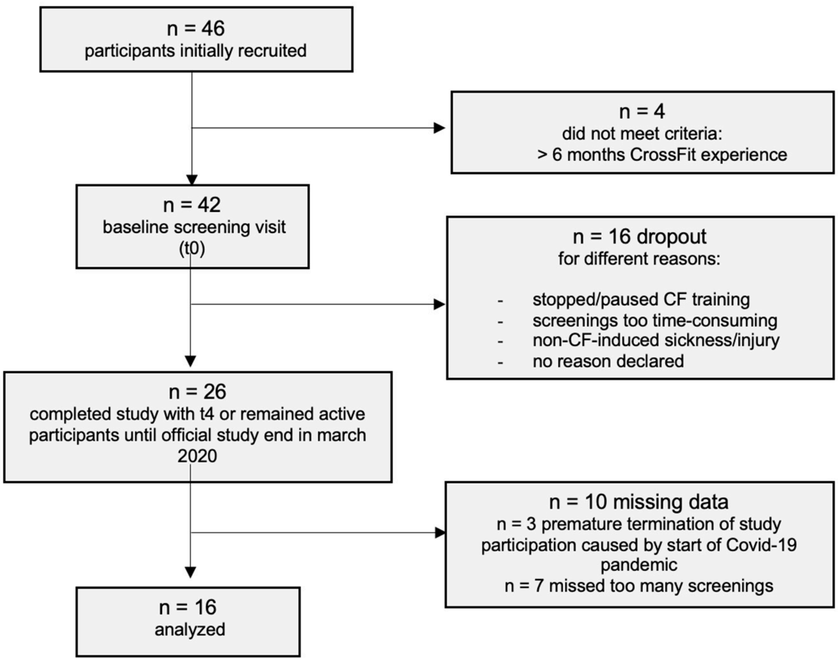

Figure 2. Flowchart of participants from recruitment to analysis.

3.1. Descriptive Statistics

The baseline (t0) statistics of all subjects who completed the intervention are listed in Table 1. Age ranged between 23 and 55 years. Two subjects were former smokers.

Exercising behavior changed throughout the study. At t0, CF was performed on 2.3 ± 0.6 days a week for 1 ± 0.3 h per session. At t4, average CF sessions per week increased significantly to 3.6 ± 1.6 days for 1.2 ± 0.3 h per session (t(13) = −3.41, $p = 0.002$). Next to CF, 75% ($n = 12$) practiced other sports on 1 ± 1.4 days per week at t0. Endurance sports were the most frequently mentioned additional sport in 56.3% ($n = 9$) of the cases. At t4, the participation in other sports slightly decreased to 62.5% ($n = 10$). Still, 43.8% ($n = 7$) mentioned endurance sports as the additional workout of the week. Of the participants, 87.5% (n = 14) reported playing sports in their childhood and adolescence, on 3.6 ± 1.3 days per week (Appendix B, Table A2).

Table 1. Anthropometry and demographics of the final n = 16 participants at baseline (t0).

	All Participants (n = 16)	Males (n = 14)	Females (n = 2)
Male (%)	87.5		
Female (%)	12.5		
Age (y)	35 ± 6.8	36 ± 6.4	28 ± 7.1
Height (cm)	180.6 ± 8.6	182.9 ± 5.9	164.0 ± 5.7
Weight (kg)	85.5 ± 19.1	88.6 ± 18.3	66.1 ± 4.5
BMI (kg/m^2)	26.1 ± 4.6	26.3 ± 4.8	24.7 ± 3.3
Body fat (%)	21.1 ± 7.2	20.4 ± 7.4	26.3 ± 0.4
Muscle mass (%)	75.0 ± 6.8	75.7 ± 7	69.9 ± 0.3
Resting metabolic rate (kcal)	1962.3 ± 321.1	2032.7 ± 274.3	1469.0 ± 110.3
Resting heart rate (bpm)	65.9 ± 9.6		
Current smoker (%)	6.3 (n = 1)		
Sedentary occupation (%)	100 (n = 16)		

Values expressed as mean ± SD; BMI: body mass index; bpm: beats per minute; sedentary occupation: mostly sitting at work.

3.2. Primary Endpoint VO_2max

VO_2max significantly increased (F (2, 30) = 5.617, $p < 0.01$, $\eta_p^2 = 0.27$) (Table 2) with the most prominent increase between t0 and t4 (Mdiff = 4.97, [0.12, 9.73]). VO_2 data were not normally distributed ($p < 0.05$). Additional analysis by the Friedman test confirmed a significant increase in VO_2max ($\chi^2(2) = 7.63$, $p = 0.022$) (Appendix B, Table A3). A significant change in HRR from t0 to t4 could be observed both in the early phase at 1 min post-exercise (F (2, 20) = 5.08, $p < 0.05$, $\eta_p^2 = 0.34$) and in the late phase at 5 min post-exercise (F (2, 20) = 3.71, $p < 0.05$, $\eta_p^2 = 0.27$) (Table 2).

Table 2. Characteristics of CPET variables and well-being throughout the intervention.

	n	t0 M [95% CI]	t2 M [95% CI]	t4 M [95% CI]	Difference t0–t4	ANOVA p	η_p^2
VO_2max (mL/min/kg)	16	43.3 [37.6, 49.1]	47.2 [42.2, 52.1]	48.3 [43.9, 52.7]	5 [0.1, 9.7]	0.008 *	0.27
Wattage max (W)	16	275.2 [243.7, 306.8]	275.0 [249.5, 300.5]	276.4 [238.8, 313.9]	0.4 [−15.3, 16.0]	1.000	0.00
Watt/kg max	16	3.3 [2.9, 3.8]	3.3 [2.9, 3.8]	3.3 [2.8, 3.8]	−0.1 [−0.3, 0.2]	1.000	0.01
HR max (bpm)	16	173.6 [164.5, 182.8]	174.3 [163.9, 184.7]	171.9 [159.4, 184.4]	1.1 [−4.1, 6.3]	1.000	0.07
HRR 1 min (bpm)	16	143.8 [135.8, 151.9]	142.1 [129.5, 154.7]	132.1 [120.2, 144.0]	11.7 [−10.9, 14.3]	0.040 *	0.34
HRR 5 min (bpm)	16	114.5 [107.6, 121.3]	110.9 [102.1, 119.8]	106.5 [97.6, 115.5]	7.9 [0.0, 15.8]	0.049 *	0.27
	n	t0 M [95% CI]		t4 M [95% CI]	Difference t0–t4	t-test p	d
Well-being (%)	16	60.5 [52.2, 67.9]		69.2 [61.1, 76.9]	8.7 [2.4, 15]	0.005 *	0.59

Inner-subject effects of time presented as mean and [95% confidence interval]; VO_2max = maximum oxygen uptake; HR max = maximum heart rate (bpm), HRR = heart rate recovery: HR in bpm at 1 min and 5 min post-exercise; each from t0 to t4; * $p < 0.05$; effect size as η_p^2; Well-being in % at t0 and t4, effect size presented as Cohens' d.

To develop a deeper understanding of the effect of CF training on VO_2max, the percentual changes from t0 to t4 were categorized for all subjects. In the category "nonresponders" (n = 6) subjects either decreased their VO_2max during the intervention or showed a negligible effect (−14.3–1.0%). N = 5 participants fell into the category "responders+", with an increase of 7.4–16.8%. Finally, the "responders++", (n = 5) raised their individual VO_2max by 23–62.5%. Comparing the VO_2max at t4 among the three categories shows, that all achieved similar values of 49.73 mL/min/kg, 47.25 mL/min/kg, and 47.58 mL/min/kg, respectively, even though at baseline, VO_2max extensively differed between the three categories (Figure 3). A Pearson product–moment correlation revealed a strong negative correlation between VO_2max at baseline (t0) and its progression in % at t4 (ΔVO_2max mL/min/kg %) (r = −0.654, p = 0.006, n = 16) (Figure 3).

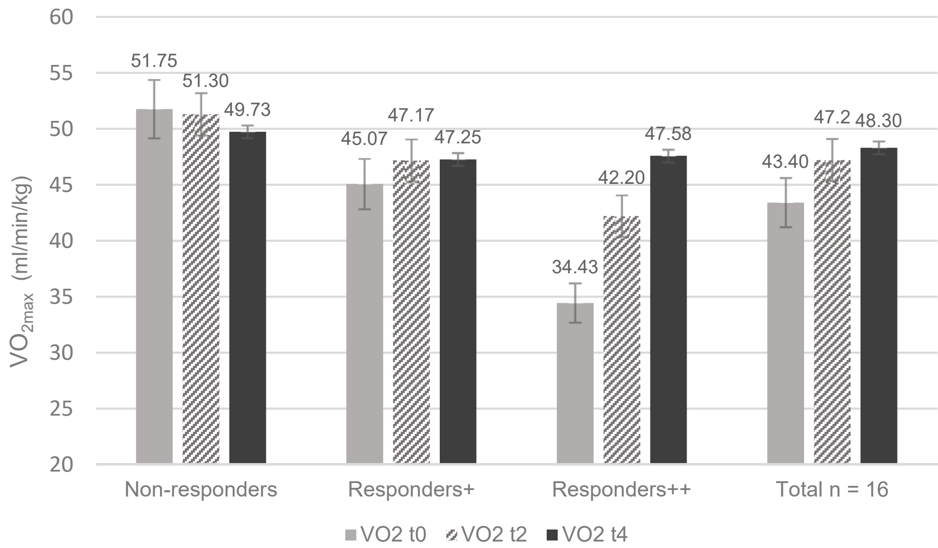

Figure 3. VO_2max (mL/min/kg) improvement (t0–t4) by category ("nonresponders", n = 6, −14.3–1.0%; "responders+", n = 5, 7.4–16.8%; "responders++", n = 5, 23–62.5%) and for the total sample. Values are shown as mean and 95% CI.

3.3. Secondary Endpoint Well-Being

Psychological well-being was assessed by the WHO-5 Index pre- and post-intervention (t0 and t4). A significant increase of 8.7% was found (t (11) = −2.24, p = 0.005, d = 0.59) (Table 2).

3.4. Exploratory

The resting metabolic rate changed significantly (F (2.3, 25.5) = 3.43, p = 0.042, η_p^2 = 0.24) (Table 3). As some data were not normally distributed, analysis by the Friedman test approved the nonsignificant development of all anthropometric measures but resting metabolic rate ($\chi^2(2)$ = 13.64, p = 0.009) (Table A4, supplement).

In order to increase the explanatory power of our analysis, in a second step we categorized our sample as follows: 1. the two female participants were taken out of the analysis; and 2. two groups were built out of the remaining n = 14 males. The groups were categorized by body composition with group one (n = 7) representing all male subjects with "high body fat" at baseline (t0), indicated by a body fat percentage of >19% and a BMI of >25. Accordingly, subjects in group two (n = 7) had a <19% body fat percentage and a BMI of <25 at baseline. The group-based analysis revealed a significant change in HRR at 1 min only for the "high body fat" group (F (2, 8) = 6.60, p < 0.05, η_p^2 = 0.62) (Table 4). In both groups, none of the remaining variables showed a significant effect for time (Table 4).

Table 3. Characteristics of anthropological parameters from t0 to t4.

	t0	t1	t2	t3	t4	Difference	ANOVA	
	M [95% CI]	M [95% CI]	M [95% CI]	M [95% CI]	M [95% CI]	t0–t4	p	η_p^2
Weight (kg)	85.5 [75.3, 95.7]	85.9 [76, 95.8]	85.2 [75.7, 94.7]	85.3 [76.2, 94.5]	83.9 [76.8, 91.1]	−1.6 [−8.4, 11.6]	0.617	0.02
BMI (kg/m^2)	26.1 [23.6, 28.5]	26.2 [23.8, 28.7]	26 [23.7, 28.4]	26 [23.8, 28.2]	25.8 [24.2, 27.4]	−0.3 [−1.4, 1.9]	0.729	0.01
Body fat (%)	21.1 [17.3, 24.9]	21.5 [17.4, 25.6]	21.7 [17.6; 25.9]	20.9 [17.2, 24.6]	19.9 [16.2, 23.5]	−1.2 [−1.7, 4.2]	0.296	0.08
Muscle mass (%)	75.0 [71.3, 78.6]	74.6 [70.7, 78.5]	74.3 [70.4, 78.3]	75.2 [71.7, 78.6]	76.2 [72.7, 79.7]	1.2 [−4.1, 1.6]	0.282	0.08
RMR (kcal)	1935.3 [1732, 2139]	1934.7 [1737, 2133]	1905.3 [1723, 2088]	1942.1 [1756, 2128]	1977.8 [1776, 2179]	42.4 [−143.3, 58.4]	0.042 *	0.24

Inner-subject effects of time; * $p < 0.05$; effect size presented as η_p^2; RMR: resting metabolic rate.

Table 4. Characteristics of CPET variables categorized by group: "high body fat" and "low body fat".

Group 1 High bodyfat	n	t0 M	t2 M	t4 M	Diff. t0–t4	ANOVA p	η_p^2
VO_2max (mL/min/kg)	7	41.8	43.2	44.7	–2.9	1.000	–0.08
Wattage max (W)	7	289.3	285.7	282.0	7.2	1.000	0.06
Wattage/kg max	7	2.9	3.0	3.1	–0.2	1.000	0.11
HR max (bpm)	7	168.7	168.7	164.1	4.6	0.271	0.31
HRR 1 min (bpm)	5	142.6	129.0	125.0	17.6	0.046 *	0.62
HRR 5 min (bpm)	5	113.2	103.8	100.4	9.4	0.087	0.57
Group 2 Low Bodyfat	n	**t0 M**	**t2 M**	**t4 M**	**Diff. t0–t4**	**ANOVA** p	η_p^2
VO_2max (mL/min/kg)	7	41.8	49.7	51.8	–6.8	0.115	0.49
Wattage max (W)	7	269.6	268.6	275.8	–6.2	1.000	0.07
Wattage/kg max	7	3.6	3.5	3.5	0.1	1.000	0.07
HR max (bpm)	7	176.7	178.0	177.7	–1.0	1.000	0.02
HRR 1 min (bpm)	5	143.6	150.0	136.6	7.0	1.000	0.47
HRR 5 min (bpm)	5	114.0	116.6	109.8	4.2	1.000	0.24

Inner-subject effects for time, analysis of variables split by group: Group 1: "High body fat" $n = 7$ males, BMI > 25, body fat percentage > 19%. Group 2: "Low body fat" $n = 7$ males, BMI < 25, body fat percentage < 19%. HRR = heart rate recovery. Watt/kg max = maximum wattage divided by body weight in kg. Values shown as mean. * $p < 0.05$; effect size presented as η_p^2.

4. Discussion

Our hypotheses for the study on hand were defined as follows: Subjects were assumed to improve 1. their body composition, with increasing muscle mass while decreasing fat mass, 2. their aerobic capacity, and 3. report an improvement in well-being throughout the group workout intervention. The main outcomes of the StartXFit trial were significant effects of time for aerobic capacity as well as psychological well-being. Resting metabolic rate significantly increased, while other anthropometric measures followed a positive but nonsignificant trend. To the best of our knowledge, this was the first study to look at long-term effects on cardiopulmonary fitness in CF beginners as a primary endpoint.

4.1. Primary Endpoint—VO_2max

All subjects reported to be predominantly sitting at work. Considering the growing body of evidence for the association between time spent sitting and CVD risk [34,35], CRF was chosen as the primary endpoint in this study. CRF is an important clinical measure to assess individual CVD risk and is often indicated as VO_2max (mL/min/kg). After nine months of CF intervention, our participants improved their VO_2max by an average of 11.5%. According to Lee et al., a 1-MET VO_2max improvement (3.5 mL/min/kg) is already associated with a 19% lower risk of CVD mortality [11]. The mean achievement of 5 mL/min/kg observed in our subjects therefore indicates the potential of regular CF training to improve individual aerobic fitness and cardiopulmonary health and lower the risk for CVD. Increased VO_2max is a product of enhanced oxygen uptake, transportation, and utilization at the cellular level. We assume that the improvement mainly resulted from the characteristic WOD part of a CF workout, which combines resistance training and anaerobic and aerobic exercises at high intensity. A recent study by Meier et al. supports this assumption. They specified that especially the WOD imposes intense cardiorespiratory stimuli, with heart rate (HR) values of $\geq$91% of HR_{max} [29]. In line with that, Helgerud et al. investigated superior VO_2max improvement through short, high-intensity running intervals at 90–95% HR_{max} in comparison to training at lower intensities at the lactate threshold or 70% HR_{max} [36]. Previous studies investigating the effects of CF on CRF appeared to be contradictory. McKenzie et al. found no significant VO_2max improvement in young females after four weeks of intervention, while specific strength parameters improved [19]. On the contrary, Murawska-Cialowicz and colleagues reported a significant VO_2max increase in women but not in men after three months of CF participation [21]. Similarly, Cosgrove et al. tested VO_2max with the Cooper test pre- and post-six months of intervention [20]. Female CF beginners (0–6 months experience) improved significantly, while those with >6 months experience did not. In men, they found no significant effect on aerobic performance. Finally, Crawford et al. failed to indicate any significant change in VO_2max in both sexes after a six-week HIFT intervention [37]. Our results add to the literature, finding that it took nine months of CF intervention to achieve a significant 11.5% change in VO_2max. At screening visit t2 (after 3–4 months), aerobic capacity improved by 8.8%, which was nonsignificant. However, it must be considered that we exclusively included CF beginners, whereas other studies tested participants with mixed experience levels. This complicates the comparison of results. Furthermore, as our sample only includes two females, an analysis based on gender is difficult.

Another finding in our study was the strong negative correlation between individual VO_2max at baseline and its change (in %) after nine months. Therefore, the better the VO_2max of a participant was at t0, the less this parameter improved in percentage at t4. Hence, especially sedentary, and unfit individuals can benefit from regular CF participation and achieve great effects on cardiovascular fitness. Previously, Cosgrove et al. reported similar results when comparing the effects of CF training in experienced and nonexperienced subjects [20]. Women with 0–6 months CF experience showed greater improvement on their 1.5-mile run than those with 7+ months experience. Furthermore, Ozaki et al. described comparable findings in their study on resistance training effects on VO_2max. They found a significant negative correlation between individual VO_2max measures at baseline and the resistance-training-induced changes at the study end [12]. These findings suggest the dependence of training induced VO_2max changes upon baseline VO_2max.

4.2. Secondary Endpoint—Well-Being

Our intervention resulted in 8.7% greater well-being among the subjects. This highlights the positive impact of CF training on mental health. Previously, only Brandt et al. investigated well-being before and after a six-month CF intervention in sedentary employees. Strikingly, they found no significant improvement. In comparison to the participants of Brandt et al.'s study, our subjects reported greater well-being at baseline (t0) (60.5% to 54.4%) and study end (t4) (69.2% to 61.6%) [24].

Prior to the intervention, as many as 87.5% of our subjects already practiced some kind of sport. We therefore cannot argue that the improvement in well-being observed here solely resulted from being physically active. However, we assume that particularly CF as a sport influenced individual well-being. Possibly, it brought a new athletic challenge to the subject's workday life, yielding physiological but also psychological effects. This assumption is supported by the increase of weekly CF sessions reported by the participants along the study duration. The study protocol prescribed a minimum of two weekly sessions.

At t0, the average was 2.3 sessions/week, which significantly increased to 3.6 sessions/week at t4. A possible explanation can be found in the philosophy of CF: for many athletes, CF does not solely encompass the physical training concept but a whole lifestyle with certain philosophies on exercise, recovery, nutrition, and even fashion [18]. Moreover, the group-based character of CF should not be underestimated. Working out in a group can enhance adherence and generate a social atmosphere [38]. Whiteman-Sandland et al. demonstrated a greater "sense of community" and belongingness among members of CF affiliates in comparison to those exercising in traditional gyms [39]. Altogether, this could explain the positive effect on well-being observed here.

4.3. Exploratory

Occupational sitting hours are associated with adverse effects on body weight and fat mass [35,40–42]. Body composition was therefore screened for exploratory purposes. Improved body composition through CF training was earlier reported, even after shorter intervention periods [21,43]. Unlike our assumptions, body weight (−1.6 kg, 1.9%) and body fat (−1.2%) showed a negative trend and muscle mass increased by 1.2%; however, these changes were nonsignificant. Only resting metabolic rate significantly rose by 42.4 kcal/day, even though mean body weight decreased. In line with our findings, Sobrero et al. reported no improvement in body composition after 10 weeks of CF intervention in sedentary women. They proposed increased appetite due to increased physical exercise as a possible reason [23]. We did not control for a change in diet or collect data on nutritional habits during the intervention, which makes assumptions difficult. Cavedon et al. found that a high weekly training load (>10 h) yielded superior changes in muscle mass, lean body mass, and fat mass when compared to less or no CF training [22].

Per definition, mean BMI at baseline (26.1 kg/m^2) and at intervention end (25.7 kg/m^2) were categorized as slightly overweight [44]. The average BMI of the sample fell into the range (24.5–36.4 kg/m^2) previously reported by other CF studies [20,24,43,45]. To reveal the underlying body composition, average fat (t0: 21.1%) and muscle mass (t0: 75%) were also tracked. Contextualizing these measures with previous CF studies suggests a high baseline fitness of our sample. Smith et al., for example, reported a BMI of 28.1 kg/m^2 for men and 25.1 for women, with a fat mass of 22.2% and 26.6%, respectively [43]. Brisebois et al. tested physically inactive adults with a BMI of 36.4 kg/m^2 for male and 26.5 kg/m^2 for female participants and an average fat percentage of 38% [45].

It is, however, striking, that an average of 3.3 weekly trainings (2.3 days CF, 1 day additional sport) did not result in a reduction of weight or body fat, nor did muscle mass increase significantly in our participants. A potential explanation will be discussed below.

The whole sample improved HRR, both at 1 min and 5 min post-exercise, which was earlier described as a strong predictor of individual CVD risk [13]. This HRR enhancement is in line with the increase in CRF and pictures an improved sympatho-vagal balance during and post-exercise in response to the CF intervention [14]. Positive effects on HRR after CF training were previously reported among cadets of the Ukranian Air Assault forces [46]. Presumably, the regular switch between high-intensity and resting intervals, which is characteristic for CF workouts, serves as a good stimulus for HRR.

For the implication of both VO_2max and body composition outcomes, some important facts have to be discussed. Firstly, in the questionnaire at t0 and t4, 75% of participants reported engaging in other sports at the same time as the intervention. Of them, 56.3% did at least one weekly endurance training at t0. At t4, the number decreased to 43.8%. Furthermore, most subjects (87.5%) had engaged in sports since their childhood and used to do as many as 3.6 weekly workouts. As stated before, this suggests a high baseline fitness, even though our subjects were CF beginners with a low activity level at work. The baseline VO_2max measures, especially those of the nonresponder group (51.8 mL/min/kg, Figure 3), suggest a high fitness level compared to up-to-date measures in a northern European population [47]. The low average fat percentage (21.1%) underscores this notion. Under these baseline circumstances, the question raises what additional improvement in aerobic capacity and body composition through the intervention could be expected in this sample.

Even though two weekly CF workouts were obligatory for study participation, some subjects completed as many as six per week. Yet, neither a significant dose–response relationship between weekly hours of CF and VO_2max improvement nor a correlation between VO_2max improvement and engagement in endurance training next to CF could be indicated. These aspects need further investigation.

4.4. Group-Based Analysis Categorized by Bodyfat

Because of the uneven distribution of male and female subjects in our sample, a second exploratory analysis was conducted with the n = 14 males categorized into two groups. The group-based analysis revealed a strong improvement of 1 min post-exercise HRR only in the "high body fat" group. As HRR 5 min post-exercise did not significantly change (Table 4), we can assume that in this group, the CF intervention especially improved the early phase of HRR, which is mainly driven by an immediate reactivation of the parasympathetic nervous system [48,49]. As stated before, HRR in general is positively correlated to training status [15–17]. This result is therefore striking, as, based on the VO_2max, we can assume a similar fitness level of both groups at t0 (Table 4). Hence, it would be interesting to address the interplay between HRR, fitness level and body composition in a future study with a larger sample size.

4.5. Risk of Bias, Dropout, and Limitations

Subjects did not receive any monetary or nonmonetary incentives for study participation. For participation in the CF classes, they paid as regular members. Therefore, no risk of bias results from any compensation for participation. The study design itself, however, holds a potential risk of bias, as we conducted a single group intervention without blinding and without a control group.

The dropout rate of 65.2% was unexpectedly high. Previous CF interventional studies with durations of >10 weeks reported dropouts of 29% [24] and 20% [43], whereas many did not clarify their dropouts. A mean drop-out of 45% for physical activity interventional studies in general was earlier reported by Marcus et al. [50]. Different reasons may explain the prior termination of 26 participants in our study. First, our nine-month intervention was longer than any other CF interventional study yet reported. It comprised two mandatory workouts/week and a total of five laboratory screenings. This time-consuming design asked for a significant commitment and engagement. Furthermore, only CF beginners were included, which involved the risk of subjects trying out CF but then terminating their participation priorly. Furthermore, the COVID-19 pandemic provided additional barriers to working out in groups and affiliates.

A clear limitation that increases the risk of bias in our study is the uneven distribution of the sexes. We lost 15 of the initial 17 female participants. Even though we tried to handle this constraint with the group-based analysis of only male subjects, a more representative sample would be preferable. Another constraint is the missing information on training load, type of training, and well-being at timepoint t2. To set the collected VO_2max and body composition measures at t2 into context, this information would be of value. Therefore, the questionnaire should have been collected at t2 as well. Furthermore, details on diet and eating habits could add important information to the analysis of body composition, especially to control if a subject's appetite was increased by the training intervention. Additionally, even though the sample was standardized in terms of CF experience level, the baseline fitness level differed among the participants (VO_2max range of 25.1–73.8 mL/min/kg, body fat range of 11.2–35.9%). Lastly, our definition of a CF beginner (<6 months experience) still allows a potential difference of 6 months in experience between the participants. This complicates the interpretation of physiological measures and body composition as discussed above.

A major strength of our trial is the long-term intervention period. For the first time, CF athletes were tracked over more than 6 months' duration. Furthermore, our intervention did not stick to a certain CF routine or protocol. We investigated participation in regular CF training as happens in a genuine CF affiliate. This ensures good external validity and increases the value for practical implications.

5. Conclusions

What stands out about this study is a significant improvement (11.5%) in VO_2max after nine months of $\geq$2 CF workouts/week in adult beginners. Another major finding was the significant increase (8.7%) in overall well-being. Also, resting metabolic rate increased significantly (2.2%). A nonsignificant positive trend on body weight, fat mass, and muscle mass was registered. These findings reveal the health and fitness-promoting effects of regular CF training, especially on cardiorespiratory parameters. The benefits were particularly promising for subjects with low baseline fitness. Due to the group-based, versatile, and time-efficient design, CF is a suitable training program, even for people with low intrinsic motivation.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of the University of the Bundeswehr Munich (6 April 2018) for studies involving humans. The trial was registered on ClinicalTrials.gov (DRKS00027059; 11 April 2021).

Informed Consent Statement: Written, informed consent for participation in the study as well as for publication of this paper was obtained from all subjects involved in the study.

Data Availability Statement: Anonymized data have been made publicly available at the Open Science Framework (osf.io) and can be accessed at: https://osf.io/h7fjq/?view_only=d03a82fe6a394f1dbd857a7c3a189620 (accessed on 28 July 2023).

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Appendix A

Appendix A.1. CrossFit

The exercise program CF combines multiple domains: Aerobic exercises (like running, cycling, or rowing), gymnastics and body weight movements (like hand stands and pull-ups), and weightlifting routines (like squats, deadlifts, clean, snatch, and overhead press). The movements range from being rudimentary to very complex and should always involve multiple joints. Exercises are either completed based on time, on repetitions, a specific distance covered, or a specific weight lifted [15]. A classical CF workout comprises 60 min, starting with a warm-up and a skill development part. Afterwards, the "Workout of the day" (WOD) of about 10–20 min follows. Every day, it focuses on alternating exercises, muscle groups and skills. As an example, the workout "Kelly" comprises 5 rounds of: 400 m run, 30 box jumps, and 30 wall balls that should be completed as fast as possible. Which WOD will appear on the agenda is unknown to the athletes in advance. The workout is summed up by a cool down, which focusses on extensive stretching.

Appendix A.2. Statistical Power

Our intervention focused on CF beginners with less than six months experience. Therefore, large effects in CRF were expected, which is in line with other studies in CF athletes of mixed fitness levels, who found significant improvements in VO_2max [21,43]. To achieve a statistical power of at least 85% with an alpha level of 0.05 (two-sided), we calculated the need for at least 18 participants using the G*Power software (version 3.1.9.6; Heinrich Heine Universität Düsseldorf, Düsseldorf, Germany). Because of the time-consuming study design, a drop-out of about 50% was expected [50]. Therefore, 46 participants were initially recruited.

Appendix B

Table A1. Anthropometry and demographics of initially recruited participants at baseline (t0).

	All Participants (n = 46)	**Males (n = 29)**	**Females (n = 17)**
Male (%)	63		
Female (%)	36		
Age (y)	33.8 ± 8.1	35.1 ± 7.3	31.5 ± 9
Height (cm)	177.2 ± 9.2	182.1 ± 7.2	168.8 ± 5.4
Weight (kg)	80.1 ± 17.8	89.1 ± 15.6	64.8 ± 8.5
Body fat (%)	23.1 ± 7.2	20.8 ± 6.5	27.0 ± 6.8
Muscle mass (%)	73.0 ± 6.9	75.3 ± 6.2	69.2 ± 6.4
Resting metabolic rate (kcal)	1819.1 ± 378.9	2056.3 ± 260.4	1414.4 ± 95.6
Current smoker (%)	6.5 (n = 3)		
Sedentary occupation (%)	93.5 (n = 43)		

Values are mean ± SD; age: at beginning of intervention; sedentary occupation: predominantly sitting at work.

Table A2. CrossFit and other sports behavior of participants at baseline (t0) and at end of intervention (t4).

	t0 (n = 16)	**t4 (n = 14)**	***p***
CrossFit: sessions/week	2.3 ± 0.6	3.6 ± 1.6	0.002 *
Hours per CrossFit session (h)	1 ± 0.3	1.2 ± 0.3	0.168
Practicing other sport (%)	75 (n = 12)	62.5 (n = 10)	
Practicing endurance sports (%)	56.3 (n = 9)	43.8 (n = 7)	
Other sports: sessions/week	1 ± 1.4	0.7 ± 1.1	
Hours per other training session (h)	0.8 ± 1.3	1.6 ± 1.1	
Practiced sports as child/adolescent (%)	87.5 (n = 14)		
Childhood sports sessions/week	3.6 ± 1.3		

Values are mean ± SD; * $p < 0.05$.

Table A3. Non-parametric Friedman test for primary outcome VO_2max (mL/min/kg).

	n	**Chi-Square**	***p***
VO_2max (mL/min/kg)	16	7.63	0.022 *

Maximum oxygen uptake (VO_2max) in mL/min/kg; * $p < 0.05$.

Table A4. Non-parametric Friedman test for exploratory endpoints.

	df	Chi-Square	*p*
Weight (kg)	16	2.41	0.662
Body fat (%)	16	2.20	0.699
Muscle mass (%)	16	2.33	0.675
Basal metabolism (kcal)	12	13.64	0.009 *
Resting heart rate (bpm)	16	0.61	0.962

bpm = beats per minute; * $p < 0.05$.

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