Fontys

Paramedic University of Applied Sciences

"The effect of interval training versus continuous training on maximum exercise capacity in patients with chronic heart failure"

A literature review

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Preface

Writing this literature review is the final step to finalize the bachelor program of physiotherapy and the last step before starting to work as a physiotherapist. The last four years have been an awesome experience preparing to apply all the knowledge I gathered, at Fontys in Eindhoven, in real physiotherapy practice.

The preparation for this bachelor thesis started in July 2013. This was the time when we had to choose a topic for this literature review. You could choose for three of your favorite topics and apply for them. The final decision about the topics was up to the teachers/supervisors. During my studies we had a period which was about the cardiac and pulmonary system. Already there I noticed that I really like that topic due to its genius complexity. The body´s way of combining and tuning so many complex systems and processes is just amazing. In my opinion the cardiovascular system was one of the most interesting topics during those four years. This is why my first choice was "Activity in chronic illness: Heart failure". And I was lucky I was allocated that topic.

I was really happy that I got that topic since I have to work with it for a long time and the motivation for writing such a paper is much higher if you are willing to learn about it. When reading scientific reports about that topic I was surprised that interval training is also applied in heart failure patients. I knew that interval training became very popular in recent years in healthy people or athletes but letting people with a cardiac disease work out at these high intensities was new for me. But this is why I thought it would be interesting to find out more about it.

Continuous training is very common in cardiac rehabilitation. So I thought it might be interesting to find out which training modality achieves better results in terms of increasing physical capacity. The starting point of my bachelor thesis was the following question: "The effect of interval training versus continuous training on maximum exercise capacity in patients with chronic heart failure". This question accompanied me during the last year of my studies. In the following pages I do my best to answer this question to the reader in an interesting way and give an update of current scientific evidence about the current topic.

There are many people to be acknowledged who accompanied me during the last four years. Family, friends and study colleagues made the time unforgettable! In the process of writing this thesis I thank Chris Burtin, my supervisor, Nicolai Eng and Katja Zimmermann for the support and feedback they provided!

Abstract

Background: Chronic heart failure is a major cause of morbidity and death in the society and one of the leading causes of hospitalization. The pathophysiology in chronic heart failure leads to a number of symptoms including decreased maximum exercise capacity which decreases quality of life of the patients. Reduced maximum exercise capacity is an important predictor for the course of the disease and reflects the amount of exertion a person can sustain. Maximum exercise capacity can be improved by exercise training. Continuous training is the most common exercise modality prescribed for chronic heart failure patients. But a recent training method has raised considerable attention in cardiac rehabilitation; the interval training method. The question arises which training modality has better effects on maximum exercise capacity in chronic heart failure patients.

Objective: The aim of this literature review is to find out if continuous training or interval training has a superior effect on maximum exercise capacity in chronic heart failure patients.

Method: Relevant articles were identified in Pubmed and CINAHL based on set inclusion criteria. The methodological quality of the articles was assessed by using the PEDro scale. In order to assess the level of evidence, a best evidence synthesis according to Van Tulder was performed.

Results: Eight articles have met the inclusion criteria and were used for data extraction. The PEDro score of the articles ranged from 4 to 5. Three of the studies showed a significant difference between the groups in favor of interval training in improving maximum exercise capacity. Four of the studies showed the same or a similar increase in maximum exercise capacity in both groups, with no significant difference between the groups. One study showed a significant increase in maximum exercise capacity in the interval training group and a non-significant increase in the continuous training group with no significant difference between the groups.

Conclusion: There is strong evidence that interval training is superior compared to continuous training in increasing maximum exercise capacity in patients with chronic heart failure.

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Introduction

Chronic Heart failure (CHF) is a major cause of morbidity and death in the society and one of the leading causes of hospitalization.[1] In 2012, 46410 people died in Germany due to the consequences of CHF[2] and in 2006 heart failure cost the German health care system 2.9 billion euros.[3] The burden of the disease is immense, especially due to the increasing number of older people in the population which are at high risk of developing CHF.[1, 4, 5] The prevalence of CHF is higher in men than in women.[5] Coronary heart disease, hypertension, heart valve disease and arrhythmias are the most common risk factors to develop CHF.[5, 6] Additionally Diabetes mellitus[5], smoking[4] and overweight are conditions predating its onset.[6]

CHF can be defined as an abnormality of cardiac structure or function leading to a failure of the heart to deliver oxygen at an appropriate rate for the requirements of the metabolizing tissues.[7] The primary abnormality in CHF is an impaired left ventricular function, leading to a fall in cardiac output, stroke volume and blood circulation.[8] To counteract those abnormalities and keep up sufficient blood circulation and oxygen supply, the body reacts with specific compensation meachnisms.[8] Increased sympathetic activation enhances heartbeat, activates peripheral vasoconstriction and several neuro-hormonal responses are triggered to compensate for the impaired pumping function of the heart.[8] These changes are functional in short term but have adverse effects in long term since the stress exerted on the ventricular wall increases and remodeling of the heart occurs.[4, 8] This leads to a further deterioration of ventricular function.[8]

Patients with CHF present with muscle changes including reduced muscle mass, abnormal muscle structure, metabolism and function.[8,9] Additionally, a reduced blood flow to active skeletal muscles occurs and slow kinetics of oxygen uptake are existent in CHF.[8,10] CHF patients are characterized by a large oxygen deficit due to the delayed oxygen delivery by the cardiopulmonary system and the disability of the skeletal muscle to extract and utilize oxygen.[10] All these abnormalities contribute to the symptoms of fatigue, lethargy, dyspnea and exercise intolerance that occur in heart failure.[8, 9, 11, 12] The existence of dyspnea and fatigue lower quality of life of patients suffering from CHF.[11]

The treatment of CHF developed and changed tremendously in the last decades.[11] In former times exercise training was thought to be contraindicated in CHF.[12] Nowadays a substantial body of evidence exists to support the use of exercise training in CHF patients and several benefits have been revealed by the use of exercise training.[12] Exercise training leads to a reversal of skeletal muscle abnormalities, improves autonomic function, delays the onset of lactate production, decreases exertional symptoms, improves quality of life, reduces mortality and increases maximum exercise capacity (VO_{2max}).[9, 10,13]

Maximum oxygen uptake (VO_{2max}) has been established as a good predictor of prognosis in CHF patients.[11] Continuous training (CT) and interval training (IT) are both used in the rehabilitation of CHF patients and have proven to increase maximum exercise capacity.[14] CT is an endurance training method applied continuously without passive or active breaks.[15] Recommended training intensities are

50–80% of VO_{2max}.[4] The duration of a session varies from 20 to 60 minutes and it is recommended to work out 3-5 days per week.[16] IT in contrast applies the basic principle that periods of high intensity exercise training are interrupted by periods of lower intensities or rest that allow a partial but often not a full recovery, which then allow the subject to re-engage in high intensity exercise bouts of "intervals".[15,17] Suggested training intensities in IT are 80-90% of VO_{2max} in intervals and active breaks at 40-50% of VO_{2max}.[4] Exercise training can be done in the form of walking, running, cycling and other activities.[17]

CT is the currently most applied and established training method in the rehabilitation of CHF patients because of its proven efficacy and safety and it is thus highly recommended in guidelines.[16] But recently, IT has raised interest in the treatment of CHF patients and has been proposed as an alternative and safe intervention in the treatment of CHF patients.[10] On the one hand IT could be more suitable for patients who have difficulty maintaining exercise continuously and on the other hand the high intensities in work interval periods could elicit a greater increase in maximum exercise capacity.[12,18] Both training methods have a positive effect on VO_{2max}, however there is no clear evidence which training modality is best to achieve the optimal training stimulus and therefore best results.[11,14,19] The current literature review will compare those two training modalities and investigate whether continuous training or interval training has a better effect on maximum exercise capacity in patients with chronic heart failure.

Method

Study design

A systematic literature review has been conducted reviewing selected randomized controlled trials (RCT).

Databases and search-string

A systematic search was conducted in the databases PubMed and CINAHL to find relevant articles for this literature review. Literature was identified using various keywords representing the patient group, the intervention, the co-intervention and the outcome. Table 1 represents the keywords. The following search-string was created: "(Chronic heart failure OR Congestive heart failure OR heart failure) AND (High intensity training OR interval training OR High intensity interval training OR Anaerobic training OR Intermittent training) AND (Endurance training OR Aerobic training OR Moderate intensity training OR Continuous training) AND (Oxygen uptake OR Maximal oxygen uptake OR Peak oxygen uptake OR Physical capacity OR Functional capacity OR VO2max OR VO2 OR Exercise capacity OR Exercise tolerance)". In PubMed Heart failure [Mesh] was used. In CINHAL the search yielded too many articles with irrelevant patient groups. Therefore "NOT COPD NOT Chronic obstructive pulmonary disease NOT Geriatrics NOT Cancer NOT Gerontology" was added to the search string.

Table 1: Keywords

Patient group	Intervention	Co intervention	Outcome
Heart failure "MeSH"	Endurance training	Interval training	Oxygen uptake
Heart failure	Aerobic training	High intensity training	Maximal oxygen uptake
Chronic heart failure	Moderate intensity training	High intensity interval training	Peak oxygen uptake
Congestive heart failure	Continuous training	Anaerobic training	Physical capacity
		Intermittent training	Functional capacity
			VO2max
			Exercise capacity
			Exercise tolerance

Inclusion criteria

Patient group:

Patient group consisting of stable heart failure patients with optimized medication and left ventricular ejection fraction (LVEF) < 40%. New York Heart Association (NYHA) stages should range from NYHA stage I-III. Subjects of any age or gender were included.

Study characteristics:

The study design had to be RCTs. Studies which were published in German or English between 1990 and 2014.

Types of intervention:

The studies had to use CT and IT as interventions. Studies were only included if they compare those two interventions

Outcome measurement:

In order to ensure comparability of the results a standard outcome measurement had to be used in all included studies. The aim of the studies should be the improvement of maximum exercise capacity. Maximum exercise capacity should be measured in VO_{2max}.

Selection of studies

The articles deriving from the search string were processed as followed: Keeping inclusion criteria in mind the first step was to screen the title. The next step was to remove the duplicates and the abstract was checked for meeting inclusion criteria. When title and abstract have shown to meet the inclusion criteria the full text was checked for inclusion criteria.

Methodological quality

The methodological quality of the final articles was assessed by using the PEDro scale. The PEDro scale was invented to score the quality of RCTs in the field of physiotherapy. The reliability of the total PEDro score is "fair" to "good".[20] This scale was introduced to prevent biased estimates of treatment effectiveness provided by low quality studies.[20] To identify these low-quality studies and assess the quality of a RCT an 11-item rating scale was designed. The items represent, e.g., the application of randomization, concealed allocation or blinding.[20] Each satisfied PEDro score item (except item 1) contributes to one point on the PEDro score.[20] The score can range from 1-10.[20] Table 2 shows the scores and the related quality.

Table 2: Classification of PEDro score[21]

Score	Methodological quality
0-3	Poor
4-5	Fair
6-8	Good
9-10	Excellent

Best evidence synthesis

To define the level of evidence and analyze the power of the conclusion a best evidence synthesis (BES) according to Van Tulder[22] was done. In table 3 the requirements for a certain level of evidence and the related level of evidence are shown.[22]

Table 3: Best evidence synthesis[22]

Evidence level	Requirements
Strong evidence	Consistent, statistically significant findings among at least two high quality RCTs
Moderate evidence	Consistent, statistically significant findings among at least one high quality RCT and at least one low quality RCT or high quality CCT
Limited evidence	Consistent, statistically significant findings among at least one high quality RCT or two high quality CCTs
Conflicting evidence	Consistent, statistically significant findings in at least one high quality CCT or one low quality RCT
No evidence from trials	In case of results that do not meet the criteria for one of the above mentioned levels of evidence, or in case of conflicting results among RCTs and CCTs

In this literature review studies scoring five or higher than five in the PEDro score were considered as high quality in the BES. The reason for this is that the PEDro scale includes two items about blinding (item 5: Blinding subjects, item 6: Blinding therapist) which cannot be achieved due to the nature of the topic. This leads to a maximum achievable PEDro score of eight.

Results

Selection of studies

Eight articles[10,19,23-28] have been found through a detailed search in PubMed and CINAHL. Figure 1 illustrates the process of selection of studies. The number of articles being extracted or excluded by each step can be followed. The search was based on applying inclusion criteria in every step taken.
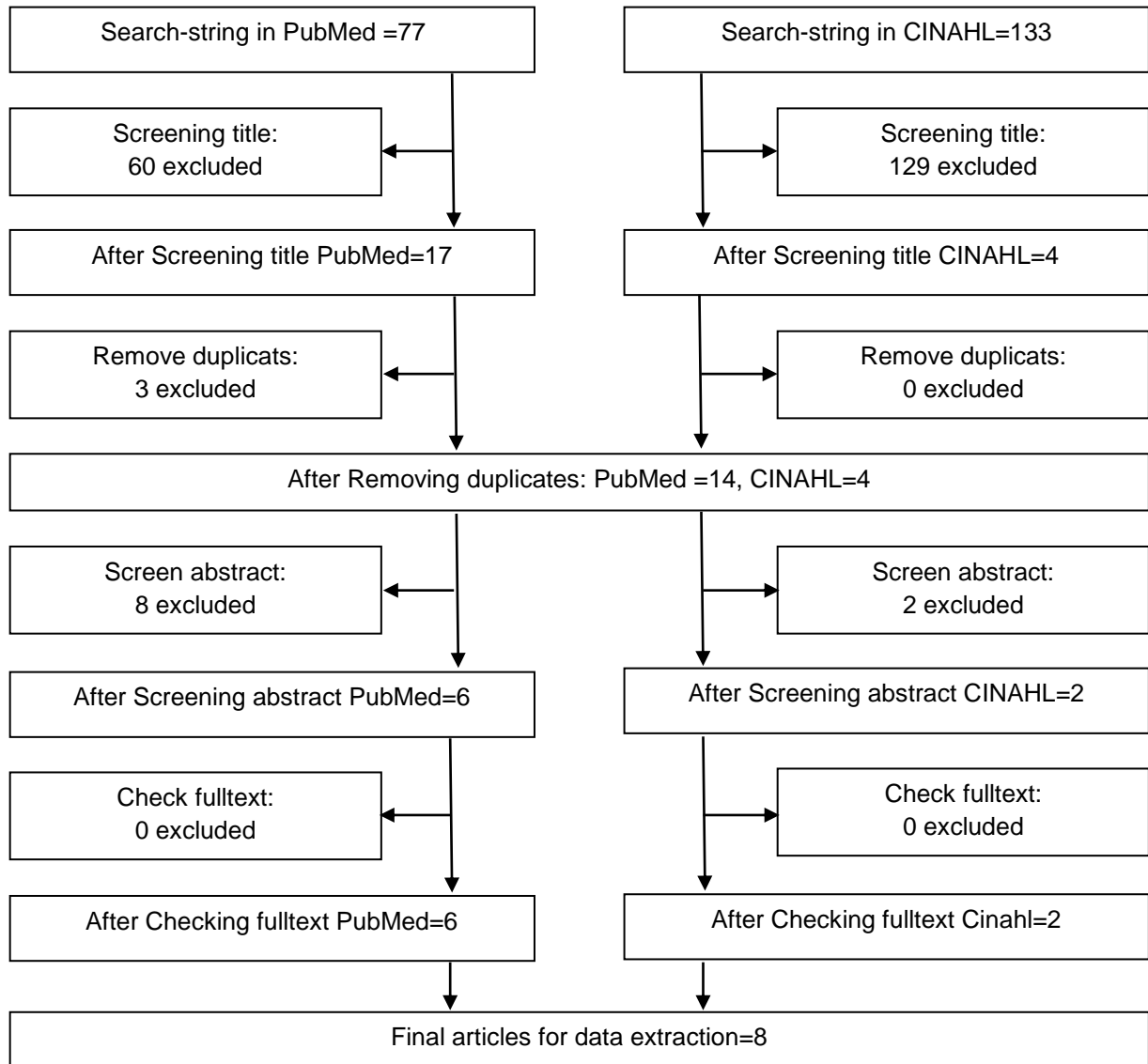
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Figure 1: Selection procedure

Baseline characteristics

Eight studies were included as final articles. The patient characteristics at baseline are shown in table 4. The number of subjects participating in the studies ranged from 18[28] to 40[24]. The total number of participants in this review was 202 with 166 male and 36 female subjects.[10,19,23-28] The average age varied from 46.7[24] to 75.0[28] years. In three of the studies[10,23,24] the subjects were in NYHA stage I-III and in another three studies[19,25,26] the patients were in NYHA stage II-III. Two of the studies[27,28] did not mention in which NYHA stage the subjects were in. The baseline values of VO_{2max} were similar in the IT/CT-groups of a study. The lowest VO_{2max} value was 10.6±4.1ml/kg/min[27] and the highest 18.8±4.6 ml/kg/min.[19]

Table 4: Patient characteristics at baseline

Author	Number of patients M/F	Average Age in years	NYHA Stage I-IV	VO_{2max} IT group in ml/kg/min	VO_{2max} CT group in ml/kg/min
Roditis[10]	19/2	62.0	I-III	14.2±3.1	15.3±4.4
Iellamo[19]	20/0	62.4	II-III	18.8±4.6	18.4±4.3
Dimopoulos[23]	23/1	61.5	I-III	15.4±4.7	15.5±3.7
Nechtwatal[24]	37/3	46.7	I-III	18.5±4.1	17.2±6.0
Smart[25]	21/2	61.0	II-III	12.2±6.5	12.4±2.5
Fu[26]	19/11	66.9	II-III	16.0±1.0	15.9±0.7
Freyssin[27]	13/13	54.5	n.m.	10.7±2.9	10.6±4.1
Wisløff[28]	14/4	75.0	n.m.	13.0±1.6	13.0±1.1

M; Male, F; Female, NYHA; New York Heart Association, VO_{2max}; Maximal oxygen uptake, IT; Interval training, CT; Continuous training, ml; Milliliter, kg; Kilogram, min; Minute, n.m.; not mentioned, ±; Data are mean ± SD

Methodological quality

The PEDro score ranged from 4-5 in all the studies.[10,19,23-28] Five studies had a PEDro score of 5[10,24,26-28] and three studies had a PEDro score of 4.[19,23,25] The detailed information showing for which item a single article scored can be found in the appendix (Appendix I). The detailed description for each item can also be found in the appendix (Appendix II)

Exercise protocols

Table 5 shows the exercise protocols. The duration of the studies ranged from 3[24] to 16[25] weeks, with 12 weeks[10,19,23,26,28] being the most common. The number of sessions varied from three to six sessions[24,27] per week with three sessions per week[10,19,25,26,28] being applied most often. Two of the studies[19,28] used uphill treadmill walking as an intervention, five studies[10,23-26] used bicycle ergometers and one study[24] used treadmill walking and biking.

In the continuous groups the duration of a single session varied from 15[24] to 47[28] minutes. In the interval groups the work intervals ranged from 30s[10,23,24,27] to 4 min[28] and the break periods varied from 30s[10,23] to 3 min.[19,26,28] In some studies they had active breaks[19,24,26,28] and in others they used passive breaks.[10,23,25,27]

To be able to set the intensity, all the studies did an incremental test before the program began.[10,19,23-28] Some authors set the intensity by using heart rate at first ventilator threshold (HR_{VT1})[27], others used Heart rate reserve (HRR)[19], maximum heart rate (HRp)[24,28], VO_{2max}[25,26] or peak work rate (WRp)[10,23,27]. The intensity of the continuous training varied in most studies. Freyssin et al. set the intensity of CT to HR_{VT1}.[27] In Nechwatal et al´s study the intensity was 75% of HRp[24]. Iellamo et al. used 45-60% of HRR.[19] In Wisløff et al´s study they walked at 70-75% of HRp.[28] In the study conducted by Smart et al. subjects cycled at 60-70% of VO_{2max}.[25] Roditis et al. and Dimopoulos et al. set the intensity at 50% of WRp.[10,23] In the study conducted by Fu et al. the subjects cycled at 60% of VO_{2max}.[26] In the interval groups of three studies the work interval intensity was set by using WRp.[10,23,27] 50% of WRp were used in Freyssin et al.´s study.[27] 100% of WRp were used in the studies conducted by Roditis and Dimopoulos.[10,23] Nechwatal et al.[24] used 50% of Watt achieved in the steep ramp test. Two other studies used VO_{2max} to define the intensity during work intervals.[25,26] Smart´s subjects cycled at 60-70% of VO_{2max}[25] and Fu´s subjects at 80% of VO_{2max}.[26] In another study[19] the intensity of the intervals was at 75-80% of HRR and in Wisløff´s study[28] the interval intensity was at 90-95% of HRp.

Table 5: Exercise protocols

Author	Work Interval intensity in IT	Break period intensity in IT	Intensity in CT	Duration/ Session IT in minutes	Ratio work : break interval	Duration/ Session CT in minutes	Sessions/ week	Duration in weeks
Roditis[10]	100%WRp	passiv	50%WRp	40	30:30s	40	3	12
Iellamo[19]	75-80% HRR[+]	45-50% HRR[#]	45-60% HRR[#]	37	4:3min	30-45	2-5	12
Dimopoulos[23]	100% WRp	passiv	50%WRp	40	30:30s	40	3	12
Nechwatal[24]	50%W at srt	15w	75% HRp[+]	15	30:60s	15	6	3
Smart[25]	60-70% VO_{2max}[+]	passiv	60-70% VO_{2max}[+]	60	60:60s	30	3	16
Fu[26]	80% VO_{2max}[+]	40% VO_{2max}[^]	60%VO_{2max}[+]	30	3:3min	30	3	12
Freyssin[27]	50%/80%WRp	passiv	HR at VT1^{+}	71	30:60s	45	6	8
Wissløf[28]	90-95 HRp[++]	50-70 HRp[#]	70-75HRp[+]	38	4:3min	47	3(1HB)	12

IT; Interval training, CT; Continuous training, HRp; Heart rate peak, min; Minutes, HB; Home-based, WRp; Work rate peak, HR; Heart rate, VT1; First ventilator threshold, s; Seconds, VO_{2max}; maximum oxygen uptake, HRR; Heart rate reserve, Str; Steep ramp test, ^;Low intensity according to ACSM, #;Moderate intensity according to ACSM, +; High intensity according to ACSM, ++; Very high intensity according to ACSM,+++; Maximum intensity according to ACSM, ACSM Table can be found in Appendix III

Outcomes on maximum exercise capacity

Table 6 illustrates the changes of VO_{2max} after the intervention. Three studies showed that VO_{2max} increased significantly more in the IT group compared to the CT group. [26,27,28] In one study VO_{2max} increased non-significantly with CT and showed a significant increase with IT.[25] A non-significant difference between the two groups was found.[25] In the other four studies there was a similar or same increase in VO_{2max} in both training groups with no significant difference between groups.[10,19,23,24] The biggest improvement in VO_{2max} with the application of IT was a 46% ($p < 0.01$)[28] , 27% (<0.001)[27] and 22.5% (<0.05)[26] increase in Wisløff et al.´s, Freysinn et al.´s and Fu et al´s study, respectively. The lowest increase in VO_{2max} was found in Fu et al.´s CT group with 1% (p>0.05)[26] and in Freyssin et al.´s CT group with 2% (p>0.05)[27] increase in VO_{2max}. The increase of maximum exercise capacity between baseline and follow-up ranged from 8%[10,23,24] to 46%[28] in the interval groups and from 1%[26] to 22%[19] in the continuous groups.

Table 6: Results on maximum exercise capacity

Authors	IT at baseline in ml/kg/min	IT after intervention in ml/kg/min	Increase In IT	P Value within IT group	CT at baseline	CT after intervention in ml/kg/min	Increase in CT in %	P Value within CT group	P-Value between groups
Roditis[10]	14.2±3.1	15.4±4.2	8	0.03	15.3±4.4	16.6±4.5	9	0.03	0.6
Iellamo[19]	18.8±4.6	23.0±4.3	22	<0.05	18.4±4.3	22.5±3.1	22	<0.05	>0.05
Dimoupolus[23]	15.4±4.7	16.6±4.9	8	<0.02	15.5±3.7	16.4±3.8	6	0.01	>0.05
Nechwatal[24]	18.5±4.1	20.0±4.5	8	0.028	17.2±6.0	18.8±6.5	9	0.006	>0.05
Smart[25]	12.2±6.5	14.7±4.5	21	0.03	12.4±2.5	14.0±4.0	13	0.12	0.72
Fu[26]	16.0±1.0	19.6±1.2	22.5	<0.05	15.9±0.7	16.0±1.5	1	>0.05	<0.05
Freyssin[27]	10.7±2.9	13.6±3.2	27	<0.001	10.6±4.1	10.8±4.1	2	>0.05	0.001
Wisløff[28]	13.0±1.6	19.0±2.1	46	<0.01	13.0±1.1	14.9±0.9	14	<0.01	<0.001

IT; Interval Training, CT; Continuous Training, ml; Milliliter, kg; Kilogram, min; Minute, ± Data are mean ± SD.

Best evidence synthesis

Effectiveness of IT compared to CT:

Three high quality RCTs show consistent, statistically significant findings that IT is superior compared to CT in improving maximum exercise capacity in CHF patients[26-28], resulting in a strong evidence for this statement.

Discussion

Summary of results

The aim of this literature review was to investigate whether CT or IT has a superior effect on maximum exercise capacity in CHF patients. The results suggest that IT compared to CT has greater benefits.[10,19,23-28] Three studies show a significant difference between the groups in favor of IT compared to CT.[26,27,28] Although, somewhat contrasting, but five studies showed no difference between the groups.[10,19,23,24,25] The finding that IT might be superior to CT are in accordance with Meyer et al. who stated in a recent review that IT has better effects on maximum exercise capacity than CT in CHF patients.[29] Also, the results of this literature review show that continuous training did not have a superior effect in any of the studies.[10,19,23-28] There are several reasons why interval training might yield better results. Having a closer look at the exercise protocols of the IT groups of the studies which showed a significant difference between the groups is therefore crucial.

Comparison of exercise protocols

The study conducted by Wisløff et al. achieved by far the biggest improvement in maximum exercise capacity.[28] The reason for this positive result could be due to the high intensity used in the work interval periods (90-95% of HRp) and the long work interval period of 4 minutes. Also, active breaks at a moderate to high intensity (50-70 % of HRp) might have contributed to the large increase in maximum exercise capacity. Another study by Fu et al.[26] which used a similar training protocol as in Wisløff et al.´s study[28] also achieved a significant increase of 22.5% of VO_{2max} for the IT group with a significant difference between the CT and IT group.[26] High intensities, long work interval times and active break periods seem to be promising to get good results. The cardiac rehabilitation guideline of the Koninklijk Nederlands Genootschap voor fysioterapie [KNGF] (2011) also supports the use of training protocols as applied by Wisløff et al. or Fu et al.. According to the KNGF it is recommended that an IT of four 4 minute blocks at 80-90% of VO_{2max} separated by 3 minutes active recovery at 40-50% of VO_{2max} is used in CHF patients.[4]

Assuming that the exercise protocol of Wisløff et al. and Fu et al is the reason for the significantly higher increase in maximum exercise capacity in the IT groups, the results reported by Freyssin et al. are surprising. Freyssin et al.´s study also achieved a significantly higher increase in VO_{2max} in the IT group compared to the CT group.[27] In Freyssin et al.´s study work interval intensity was 50% of WRp in the first 4 weeks and 80% of WRp in the last four weeks and the work interval-break ratio was much shorter (30s:60s). Work Intervals were separated by passive breaks.[27] So even though lower intensities, shorter intervals and passive breaks were applied in Freyssin et al.´s study, the results are still good. Possible reasons for the improvement in Freyssin et al.´s study might be the long duration of a single session and the high frequency per week. Another aspect to be mentioned is that in the study by Freyssin et al. the subjects in the CT group and the IT group did additional exercise in the form of balneotherapy and gymnastics (including strength exercises, stretching and relaxation) which might

have influenced the outcome. However since both, the CT and IT- group, took part in those additional training modalities it can still be said that IT had greater effects. Besides, in Freyssin et al.´s study subjects had a low baseline VO_{2max} compared to the other studies. And since VO_{2max} increases faster when a low baseline value is present[30] good results might be achieved with a lower stimulus. The subjects in Freyssin et al.´s study had the lowest baseline VO_{2max} values of all the reviewed studies and can be seen as more deconditioned. It might be assumed that Freyssin et al. chose this training protocol adapted to the lower maximum exercise capacity of the subjects in this study. This might lead to another point to focus on when choosing training protocols. The patient's capabilities and stage of deconditioning should be considered.[29]

The answer why IT is superior to CT cannot be clearly answered when looking at the IT training protocols of the studies which had better results in the IT groups since they used different intensities, durations of work intervals and break periods. But it might be suggested that the nature of IT with the higher intensities and therefore the higher stimulus in work interval periods triggers a more intense body response than the continuous stimulus of lower intensity in CT.

The current literature review detected that there is no uniformity in IT exercise protocols. And it has been shown that different training protocols induce positive effects on VO_{2max} but Wisløff et al.´s training protocol seems to yield greatest results. The problem which arises with Wisløff´s training protocol is that it might not be feasible in more deconditioned patients since they might not be able to keep up with the long high intensity work intervals and active breaks at moderate to high intensities. CHF patients who can tolerate training protocols as suggested by Wisløff et al.[28] might profit most. However, for more deconditioned CHF patients training protocols as suggested by Freyssin et al.[27] might be used as an alternative. All in all, all three protocols[26,27,28] have shown to yield greater effects than the continuous training method. Still the aim of generalization and optimization of IT training protocols should be established.

Safety of IT and CT in CHF patients

Since CHF patients are more at risk of sudden cardiac death when training, especially with vigorous exercise, safety is an important aspect to consider.[31] Meyer et al. states that IT appears to be safe in CHF patients.[29] Another study reported that both exercise modalities, CT and IT, seem to be safe in CHF patients.[32] This is in accordance with the studies in this literature review.[10,19,23-28] In studies which gave information about adverse events, no adverse events due to training were reported and interval or continuous training appears to be safe in this study population. [24,25,27,28] Only one in 202 patients in total discontinued the study conducted by Iellamo et al. due to the occurrence of permanent atrial fibrillation.[19]

Dropouts

Another critical point in exercise training in CHF patients is adherence to training in long and short-term.[33] It remains a challenge to make CHF patients train on a regular basis.[33] Lack of motivation, non-compliance or orthopedic problems were the reasons for dropouts in this literature review.[10,19,23-28] In the studies which mentioned dropouts (including 172 subjects), 18 subjects discontinued the studies.[10,19,23-25,27,28] Still this dropout rate might be considered as relatively low and be related to the fact that all the training programs were supervised or partly supervised (Wisløff et al included one home based exercise training per week). Supervision has shown to be related to higher participation and increased motivation of patients.[9] Furthermore, according to McKelvie et al., the patient´s adherence to training reduces remarkably over long term when home-based exercise is applied.[9] It can be speculated that supervised training is more suitable in this patient group since it lowers dropout rates and more safety is provided in a supervised environment.

Effect of exercise training on mortality, autonomic function, cardiac abnormalities, endothelial function and muscle abnormalities

Exercise training also has positive effects on other parameters. In the following these parameters and how they have been influenced by IT or CT will be discussed. According to Meyer et al. there appears to be a direct relation between maximum exercise capacity and mortality.[34] Meyer et al. investigated this relation in cardiovascular disease patients (including heart failure patients) and healthy subjects during a mean follow up of 6.2 years (SD±3.7 years). His results suggest that maximum exercise capacity measured in metabolic equivalents (MET) was the strongest predictor of the risk of death.[34] With each 1-MET increase a 12% improvement in survival was recorded.[34] In the study by Wisløff et al.[28], the IT group had an average increase of 1.7 METs which would suggest that the subjects in the IT group theoretically would have a 20% improvement in survival. Since exercise training increases maximum exercise capacity[10,19,23-28], it can be assumed that exercise training increases survival rates. This is in line with other studies which state that exercise training can reduce mortality.[13,34,35]

It has been shown that IT might have a better effect on maximum exercise capacity, but other important factors which are impaired in CHF patients like an imbalance of the autonomic nervous system, structural abnormalities of the heart, decreased blood flow or muscle changes have to be considered too.[8-10] The sympathetic nervous system is more active in CHF patients to compensate for the reduced oxygen supply due to the decreased pumping function of the heart.[8] According to Dimopoulos et al. CT rather than IT induces beneficial effects on autonomic function.[23]

Another characteristic of CHF patients is the reduced left ventricular ejection fraction (LVEF) due to the structural abnormalities of the heart.[8] It is feared that exercise training leads to a further deterioration of left ventricular function by provoking remodeling.[35] Nechwatal et al., Smart et al. and Wisløff et al. assessed LVEF and ventricle thickness and found no adverse changes in the CT group and in the IT group.[24,25,28] Dubach et al. investigated whether IT worsens structural abnormalities of the heart.[26] He is in accordance with Nechwatal et al.[24], Smart et al.[25] and Wisløff et al.[28] and states

that IT did not increase myocardial damage.[36] Results from Wisløff et al.´s study suggest that IT even induced reversal of remodeling and LVEF was increased by 35% (p<0.01).[28] This change has not been found in the CT group.[28] Since remodeling of the heart is a major pathological feature of CHF[8], IT might be of great importance in the treatment of CHF patients.

Abnormalities of the heart lead to a reduced stroke volume, pumping efficiency and reduced blood flow in CHF patients.[8,9] Nechwatal et al. established no improvement in those parameters in the CT group, but a significant improvement in stroke volume, pumping efficiency and a reduced peripheral resistance was found in the IT group.[24] Wisløff et al. found similar results. Stroke Volume and pumping efficiency were only influenced positively by the IT group.[28] Skeletal muscular blood flow[26,28] oxygen utilization and metabolic adaption in skeletal muscle was enhanced by the application of IT and showed no improvement in the CT groups.[28]

The present results show that IT might have a superior effect not only on the main outcome, maximum exercise capacity[26-28], but also on cardiac abnormalities[28], blood flow and oxygen utilization.[24,26,28] Furthermore, the risk of recurrent cardiac events and mortality might be reduced.[34]

Importance of the results for clinical practice

The outcomes of the present literature review have an important value in clinical practice. Specialized physiotherapists and members of cardiac rehabilitation programs should be informed about scientific background and available evidence when training CHF patients. When choosing an exercise program in cardiac rehabilitation IT might be privileged compared to CT. The patient might profit most from IT as the results suggest. Another important factor which might lead to opt for IT is the patient´s enjoyment of training. In the study by Wisløff et al., patients experienced IT as more enjoyable due to the varied procedure. In contrast to CT which was found to be "quite boring".[28] Besides, in Wissløf´s study IT had a bigger impact on the improvement of quality of life than CT.[28]

Strengths, weaknesses and perspective

A strong point of this literature review is that all the included studies stated the statistical significance between the groups. This was a crucial point to answer the question of this report. Furthermore, all of the studies used the same outcome measurement which assured comparability of the results. Another strong point is that the literature review has been peer reviewed by two students and the progress of the work was accompanied by a supervisor. A weakness of this literature review is that it has been conducted by only one reviewer. The studies included had small sample sizes and the subjects were predominantly male or exclusively male. This reduces the generalizability of the findings of this literature review. Furthermore, the variability in training protocols applied in the studies made the comparability of the outcome more difficult. High quality RCTs including greater sample sizes should be conducted in consideration of a more equal gender distribution. Further research should be done to confirm safety of IT also in more severe CHF patients. Optimization and conformity of IT training protocols should also be addressed considering the stage of deconditioning of the patient.

Conclusion

There is strong evidence that interval training has superior effects than continuous training in increasing maximum exercise capacity in chronic heart failure patients. The administration of interval training in the rehabilitation of chronic heart failure patients seems to yield good results on maximum exercise capacity, but the small sample sizes in the reviewed studies result in the need for larger studies about that topic. Further research in the form of large high quality randomized controlled trials with equal gender distribution should be conducted.

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Appendix

Appendix I: PEDro scale results

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Roditis[10]	0	1	0	1	0	0	1	0	0	1	1	5
Iellamo[19]	1	1	0	1	0	0	0	0	0	1	1	4
Dimopoulos[23]	1	1	0	1	0	0	0	0	0	1	1	4
Nechwatal[24]	1	1	0	1	0	0	0	1	0	1	1	5
Smart[25]	0	1	0	1	0	0	0	0	0	1	1	4
Fu[26]	1	1	0	1	0	0	0	1	0	1	1	5
Freyssin[27]	1	1	0	1	0	0	0	1	0	1	1	5
Wissløf[28]	1	1	0	1	0	0	0	1	0	1	1	5

Criteria 1-11:

1. Eligibility criteria

2. Randomization

3. Concealed allocation

4. Similar groups at baseline

5. Blinding subjects

6. Blinding therapist

7. Blinding assessor

8. Measured key outcome > 85% of subjects

9. All subjects received intervention as allocated or intention to treat analysis

10. Results between group statistical comparison

11. Point measurement and measurements of variability

Appendix II: Detailed PEDro criteria description

Criterion 1   This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study.

Criterion 2   A study is considered to have used random allocation if the report states that allocation was random.
The precise method of randomisation need not be specified. Procedures such as coin-tossing and dice-rolling should be considered random. Quasi-randomisation allocation procedures such as allocation by hospital record number or birth date, or alternation, do not satisfy this criterion.

Criterion 3   Concealed allocations means that the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to. A point is awarded for this criteria, even if it is not stated that allocation was concealed, when the report states that allocation was by sealed opaque envelopes or that allocation involved contacting the holder of the allocation schedule who was "off-site".

Criterion 4   At a minimum, in studies of therapeutic interventions, the report must describe at least one measure of the severity of the condition being treated and at least one (different) key outcome measure at baseline. The rater must be satisfied that the groups' outcomes would not be expected to differ, on the basis of baseline differences in prognostic variables alone, by a clinically significant amount.
This criterion is satisfied even if only baseline data of study completers are presented.

Criteria 4, 7-11   Key outcomes are those outcomes which provide the primary measure of the effectiveness (or lack of effectiveness) of the therapy. In most studies, more than one variable is used as an outcome measure.

Criterion 5-7   Blinding means the person in question (subject, therapist or assessor) did not know which group the subject had been allocated to. In addition, subjects and therapists are only considered to be "blind" if it could be expected that they would have been unable to distinguish between the treatments applied to different groups. In trials in which key outcomes are self-reported (eg, visual analogue scale, pain diary), the assessor is considered to be blind if the subject was blind.

Criterion 8   This criterion is only satisfied if the report explicitly states both the number of subjec   initially allocated to groups and the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time.

Criterion 9   An intention to treat analysis means that, where subjects did not receive treatment (or the control condition) as allocated, and where measures of outcomes were available, the analysis was performed as if subjects received the treatment (or control condition) they were allocated to. This criterion is satisfied, even if there is no mention of analysis by intention to treat, if the report explicitly states that all subjects received treatment or control conditions as allocated.

Criterion 10   A between-group statistical comparison involves statistical comparison of one group with another. Depending on the design of the study, this may involve comparison of two or more treatments, or comparison of treatment with a control condition. The analysis may be a simple comparison of
outcomes measured after the treatment was administered, or a comparison of the change in one group with the change in another (when a factorial analysis of variance has been used to analyse the data, the latter is often reported as a group × time interaction). The comparison may be in the form hypothesis testing (which provides a "p" value, describing the probability that the groups differed only by chance) or in the form of an estimate (for example, the mean or median difference, or a difference in proportions, or number needed to treat, or a relative risk or hazard ratio) and its confidence interval.

Criterion 11   A point measure is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. Measures of variability include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quantile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a Figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of
subjects in each category is given for each group.

Appendix III: ACSM table converting intensities

Table 5. Load intensities expressed in various training load measures as reported by the American College of Sports Medicine.

training aerobic endurance relative intensity				absolute intensity (in METs) for healthy older people (age in years)[a]					Strength training relative intensity[b]
intensity:	VO_{2max} (%) or HRR (%)	HRmax (%)	Borg score (6-20)	20-39	40-64	65-79	80+	Borg score (6-20)	MVC (%)
very low	< 25	< 30	< 9	< 3,0	< 2,5	< 2,0	< 1,25	< 10	< 30
low	25-44	30-49	9-10	3,0-4,7	2,5-4,4	2,0-3,5	1,26-2,2	10-11	30-49
moderate	45-59	50-69	11-12	4,8-7,1	4,5-5,9	3,6-4,7	2,3-2,99	12-13	50-69
high	60-84	70-90	13-16	7,2-10,1	6,0-8,4	4,8-6,7	3,0-4,25	14-16	70-84
very high	≥ 85	≥ 90	> 16	≥ 10,2	≥ 8,5	≥ 5,8	≥ 4,25	17-19	> 85
maximum	100	100	20	12,0	10,0	8,0	5,0	20	100

a   Maximum values are mean values achieved during training by healthy older people. The absolute intensity (in METs) was determined in men. The intensity for women is about 1–2 METs lower than that for men.
b   Based on 8–12 repetitions for persons aged < 50 years and 10–15 repetitions for persons > 50 years.
    HR_{max} = maximum heart rate; VO_{2max} = maximum oxygen uptake; * $HR_{reserve}$= HR_{max}-HR_{rest};* MVC = maximum voluntary contraction; HRR= heart rate reserve; Borg score = score on the Borg Rating of Perceived Exertion scale.