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Decrease in heart rate after longitudinal participation in the Groningen Active Living Model (GALM) recreational sports programme

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Abstract

The aim of this study was to investigate changes in heart rate during submaximal exercise as an index of cardiovascular function in older adults participating in the Groningen Active Living Model recreational sports programme who were sedentary or underactive at baseline. A repeated measurement design was conducted; 151 participants were included, providing 398 heart rate files over a period of 18 months. Multi-level analyses were conducted; growth and final models were developed. Significant decreases in mean heart rate over time were observed for all walking speeds. The covariates of sex and body mass index (BMI) were significantly related to mean heart rate at each walking speed, except for BMI at 7 $km \cdot h^{-1}$. No significant relationships were observed between energy expenditure for recreational sports activities and leisure-time physical activities and mean heart rate, except for energy expenditure for leisure-time physical activities at 7 $km \cdot h^{-1}$. From baseline to December 2002, decreases in predicted mean heart rate were 5.5, 6.0, 10.0, and 9.0 $beats \cdot min^{-1}$ at walking speeds of 4, 5, 6, and 7 $km \cdot h^{-1}$; relative decreases ranged from 5.1 to 7.4%. Significant decreases in heart rate observed during submaximal exercise reflected a potential increase in cardiovascular function after 18 months of participation in the Groningen Active Living Model recreational sports programme.

Keywords: *Heart rate, submaximal exercise, physical activity, cardiovascular function, older adults*

Introduction

Regular exercise and physical activity have been shown to contribute to a healthier lifestyle among older adults, the fastest-growing segment in European and Dutch societies (RIVM, 2007). In addition to the health benefits of physical activity, important objectives for older adults are maintaining or improving cardiovascular function and the ability to perform activities of daily living independently (ACSM, 1998a; ACSM/AHA, 2007; US Department of Health and Human Services, 1996).

Cardiovascular function can be maintained or improved by aerobic exercise programmes and can be reflected in a variety of variables, including cardiac output, arteriovenous oxygen difference, and maximal oxygen consumption ($\dot{V}O_{2max}$). Another marker of an increase in cardiovascular function is a lowering of the heart rate or bradycardia at rest and during submaximal exercise (Jurca et al., 2005; Wilmore et al., 2001). Aerobic exercise also enhances submaximal performance in older adults (ACSM, 1998a; ACSM/AHA, 2007; Wilmore & Costill, 2004).

A component that reflects cardiovascular function and is highly relevant for older adults is $\dot{V}O_{2max}$. Maximal oxygen consumption decreases by 5–15% per decade after the age of 25 years and is caused by both maximal cardiac output and arteriovenous oxygen difference. This decline is significantly accelerated by a sedentary lifestyle. Various reports show that with prolonged endurance (aerobic) exercise training, older adults elicit the same 10–30% increase in $\dot{V}O_{2max}$ as younger adults (ACSM, 1998a). The magnitude of the increase in $\dot{V}O_{2max}$ in older adults is also a function of training intensity, with light-intensity training eliciting minimal or no changes compared with high-intensity exercise.

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Indirect methods estimate $\dot{V}O_{2max}$ from maximal exercise duration, peak workload, and/or heart rate responses achieved during submaximal or maximal exercise. Increased $\dot{V}O_{2max}$ means that submaximal exercise becomes lighter (i.e. easier to undertake), reflected by a decline in heart rate response to a fixed submaximal power output on a cycle ergometer, a fixed walking or running speed (Jurca et al., 2005; Wilmore et al., 2001; Wilmore & Costill, 2004). Regular participation in moderate-intensity or more vigorous exercise can result in a range of positive cardiovascular effects. For example, over time submaximal exercise is marked by a decreased physiological demand (i.e. lower heart rate) for a given task, so that tasks that previously seemed difficult and fatiguing become easier, and enjoyable everyday pursuits can be continued for longer (Singh, 2002). Such adaptations can delay or overcome functional limitations that may otherwise be imposed by the physiological changes of ageing and disease (Singh, 2002).

It has thus become widely accepted that heart rates during steady-state submaximal exercise at the same absolute rate of work can be substantially reduced over time with aerobic exercise training. Hence a reduction in heart rate at fixed submaximal exercise over time is an objective and relevant indicator for change in cardiovascular function among older adults (Jurca et al., 2005; Wilmore et al., 2001; Wilmore & Costill, 2004).

Until now, most research on the effects of exercise on cardiovascular function has been conducted in endurance (aerobic) exercise programmes that primarily or only contained one mode of activity (e.g. running, walking). The aim of this study is to determine whether the versatile Groningen Active Living Model (GALM) programme, which consists of a diversity of recreational sports activities (e.g. softball, dance, self-defence, swimming, athletics), can also improve cardiovascular function in older adults effectively. The GALM recreational sports programme, which is primarily based on an evolutionary-biological play theory and insights of social cognitive theory, aims to stimulate these activities in sedentary and underactive older adults aged 55–65 years (De Jong et al., 2005; Stevens, Bult, de Greef, Lemmink, & Rispens, 1999). Previous results of the GALM recreational sports programme (see description below) illustrate that the overall mean intensity of the programme was 73.7% of predicted heart rate maximum (De Jong et al., 2005; Inbar et al., 1994). From baseline to 12 months, participants in the intervention and control groups increased energy expenditure for recreational sports activities to 482 and 546 kcal per week, respectively. Increases in energy expenditure for leisure-time physical activities were 207 and 1011 kcal per week for the intervention and control groups, respectively (De Jong, Lemmink, King, Huisman, & Stevens, 2007).

These changes indicate that participants increased their physical activity levels not only during the GALM programme sessions but also outside of the model, given that the mean targeted increase in kilocalories per week associated with the GALM recreational sports programme was approximately 385 kcal per week.

To determine possible adaptations in cardiovascular function, the focus of the current investigation was to evaluate the longitudinal changes in heart rate during submaximal exercise as an index of cardiovascular function after 18 months of participation in the GALM recreational sports programme.

Methods

Participants and procedures

This study was part of a broader/larger study into the effects of participation in the Groningen Active Living Model recreational sports programme on physical activity, health, and fitness, which was conducted in 2000–2003 in the Netherlands. In this broad study, a group-randomized (cluster) design was used. A total of 8504 older adults aged 55–65 years in three Dutch municipalities received written information and were visited at home to screen those who could be considered sedentary or underactive. Based on estimates of population-based data, about 60% ($n = 5102$) could be considered sedentary or underactive according to the 1998 ACSM recommendations (ACSM, 1998a). Based on a study of this type of recruitment strategy, it was projected that approximately half of the 60% ($n = 2551$) qualified for the Groningen Active Living Model (Stevens, de Jong, & Lemmink, 2008). The other half was not interested or unable to participate (personal circumstances such as illness, work, care for a family member) (Stevens et al., 1999). Ultimately, a total of 315 sedentary and underactive older adults (12% of qualified individuals) participated in all of the baseline measurements; 181 of them (57%) also participated in the follow-up measurements and were included in this study. The 134 study participants who dropped out were not significantly different with respect to sex, age, stage of motivational readiness for behavioural change, energy expenditure for recreational sports and leisure-time physical activities, or health and fitness measures (De Jong et al., 2006).

Over a period of 2 years, 181 adults were measured after each series of 15 sessions: December 2000 (T0), May 2001 (T1), December 2001 (T2), May 2002 (T3), and December 2002 (T4). Data of 28 older adults who used medication for cardiac rhythm problems were excluded. No heart rate files were collected for two participants. Among the remaining 151 participants, we collected 428 heart rate files, 30 (7%) of which were too damaged for further use. Ultimately, 398 heart rate files were used for analyses: the heart rate of five older adults was monitored on all five occasions (25 heart rate files), 27 participants were monitored on four occasions (108 heart rate files), 45 participants on three occasions (135 heart rate files), 56 participants on two occasions (112 heart rate files), and 18 participants on one occasion (18 heart rate files). Testing personnel were students with a medical or scientific background who were trained in the test procedure. The study protocol was approved by the Medical Ethics Committee of the University Medical Centre Groningen.

The Groningen Active Living Model recreational sports programme

The GALM recreational sports programme can be characterized as a versatile leisure-time physical activity programme that emphasizes moderate-intensity recreational sports activities (e.g. softball, dance, self-defence, swimming, athletics), and consists of fifteen 60-min sessions at a frequency of once a week. Participants attended three 15-session series for a period of 2 years. The control group was placed on a waiting list for 6 months before starting.

The structure of each GALM session was as follows: (1) 5–10 min warm-up; (2) 20–25 min of skills practice in which the exercises offered were differentiated according to participants' level and need, using adapted materials when necessary (e.g. foam balls); (3) 20–25 min of playing in which the skills learned and practised were applied in the context of a game or other activities; and (4) 5–10 min of cooling down consisting of flexibility and relaxation activities. All sessions were conducted in groups of 15–24 participants and held in a gymnasium located in or near neighbourhoods that the participants lived in. The sessions were led by trained instructors who, besides having a professional sports education, completed a three-day course to learn to teach the GALM sessions. For reasons of programme homogeneity, the instructors followed a scheme that prescribed the recreational sports activities and routines for GALM sessions. The frequency of the sessions was once a week and sessions lasted 60 min. Previous results illustrate that the overall mean intensity for the Groningen Active Living Model recreational sports programme was 73.7% of predicted heart rate maximum, with percentages ranging from 64.6% for the fitness session to 83.1% for the korfball session (De Jong et al., 2005); 33% of the session time could be classified as moderate and 61% as hard (ACSM, 1998b).

Measurements

The walking test with increased speed for the elderly was used, which is a performance-based field test that measures walking performance as an indicator of aerobic capacity. Participants walked on a rectangular indoor course and walking speed was paced using audio signals from a CD player. Walking speed was increased by 1 $km \cdot h^{-1}$ every 3 min, starting at a speed of 4 $km \cdot h^{-1}$ and ending at 7 $km \cdot h^{-1}$ (Lemmink, Kemper, de Greef, Rispens, & Stevens, 2001). Participants had to walk one test round to become familiar with the procedure before starting the test.

During the walking test with increased speed for the elderly, all older adults wore a Polar heart rate monitor (Accurex model, Polar Electro, Tampere, Finland). A 15-s interval was used for heart rate recording, which was synchronized with the starting audio signal from the CD player. At each walking speed, the last four heart rate samples (last minute) were averaged, thus giving steady-state mean heart rate values at walking speeds of 4 $km \cdot h^{-1}$ (HR_4), 5 $km \cdot h^{-1}$ (HR_5), 6 $km \cdot h^{-1}$ (HR_6), and 7 $km \cdot h^{-1}$ (HR_7). For reasons of standardization, participants were instructed not to eat or drink in the 2 h before the measurements.

Energy expenditure for recreational (i.e. swimming, volleyball, cycling, brisk walking) and leisure-time physical activities (i.e. gardening, doing odd jobs, walking and cycling for transportation purposes) were estimated by using two categories of the Voorrips physical activity questionnaire combined with the Compendium of Physical Activities (Ainsworth et al., 2000; Voorrips, Ravelli, Dongelmans, Deurenberg, & van Staveren, 1991).

Body mass index (BMI) was calculated from height and weight, and body fat was predicted using leg-to-leg bioelectrical impedance analysis (Tanita TBF-300, Tanita Corporation, Tokyo) (Nuñez et al., 1997).

Statistical analyses

The data were analysed using SPSS version 14.0 (SPSS Inc., Chicago, IL, 2005) and MlwiN version 2.02 (2005). Longitudinal changes in heart rate at submaximal exercise were investigated using multi-level modelling. Besides the ability of multi-level analysis to take into account possible clustering effects, it has the flexibility to deal with unbalanced data structures – for example, repeated-measures data where the data for some individuals are incomplete. Even individuals with only one measurement need not be deleted, even though they contribute little information only, and this makes it very suitable for analysing longitudinal data (Snijders & Bosker, 1999).

Based on a previous analysis, we anticipated no significant differences between the intervention and control groups (De Jong et al., 2007). Before starting the multi-level analysis, we first confirmed this assumption of no significant between-group differences ($P > 0.05$). As this was indeed the case, we combined the intervention and control groups and considered all participants as one group for further analysis.

In the present study, a two-level hierarchy was defined, with the repeated measurements (defined as level-1 units) nested within adults (level-2 units) (Singer & Willet, 2003; Snijders & Bosker, 1999). The first step in the multi-level modelling of heart rate during submaximal intensity exercise was to employ a growth model (model 1) consisting of an initial status (e.g. mean heart rate at a fixed walking speed) and the time variable (time). Next, relevant covariates (sex, BMI, energy expenditure for recreational sports activities, and energy expenditure for leisure-time physical activities) were added to the final model (model 2). Statistical significance was set at $P < 0.05$.

Results

Data from 151 participants were used for analyses. Table I presents the main characteristics of the participants at baseline. Forty-two percent of the participants were men and the average age of the total group was 59.2 years. Mean programme attendance rates (sessions attended per time frame of 6 months/maximal number of 15 sessions offered × 100%) were 74%, 72%, and 69% after 6, 12, and 18 months, respectively.

Read vertically, Table II presents the mean heart rate values per walking speed at each measurement (T0 to T4). At baseline, the mean heart rates per walking speed were 105 ($s = 15.0$) beats · min^{-1} at 4 km · h^{-1}, 118 ($s = 17.6$) beats · min^{-1} at 5 km · h^{-1}, 135 ($s = 19.3$) beats · min^{-1} at 6 km · h^{-1}, and 155 ($s = 15.5$) beats · min^{-1} at 7 km · h^{-1}, respectively (Table II). This resulted in relative heart rates of 63.5%, 71.4%, 81.7%, and 93.8% of predicted maximum heart rate, respectively (Inbar et al., 1994) (not presented).

Table III illustrates the multi-level models that were obtained at walking speeds of 4, 5, 6 and 7 km · h^{-1}. A growth model (model 1) and a final model (model 2) with the relevant covariates of sex, BMI, energy expenditure for recreational sports activities, and energy expenditure for leisure-time physical activities were calculated for each walking speed. In all final models (model 2), significant main effects for time ($P < 0.01$), sex ($P < 0.001$), and BMI ($P < 0.05$) were observed at all walking speeds, except for BMI at 7 km · h^{-1}. No interactions were found for sex × time and BMI × time ($P > 0.05$). No significant main effects were found for energy expenditure for recreational sports activities and energy expenditure for leisure-time physical activities ($P > 0.05$) either, except for leisure-time physical activities at a walking speed of 7 km · h^{-1} ($P < 0.01$). Finally, the residual variances derived from model 1 in Table III show that the residual variances for between-individuals (level 2) were about twice as large (0.55–0.72) as for within-individuals (level 1) (0.28–0.45) (not presented).

Equations that predicted the development of mean heart rate per walking speed over time of older adults participating in the GALM model programme were derived from the final model, shown in Table III. Only those covariates (sex, BMI) that were significantly associated with heart rate were included in the equations.

Equations:

$$HR_4 = 108.20\,(1.47) - 1.05\,(0.41) \times \text{time} - 12.07\,(2.00) \times \text{sex} + 0.84\,(0.28) \times \text{BMI}$$

$$HR_5 = 122.23\,(1.64) - 1.41\,(0.46) \times \text{time} - 16.08\,(2.23) \times \text{sex} + 1.04\,(0.31) \times \text{BMI}$$

$$HR_6 = 141.08\,(1.90) - 2.47\,(0.51) \times \text{time} - 18.18\,(2.50) \times \text{sex} + 0.93\,(0.37) \times \text{BMI}$$

$$HR_7 = 164.49\,(2.82) - 3.20\,(0.76) \times \text{time} - 16.78\,(3.18) \times \text{sex} + 0.62\,(0.48) \times \text{BMI}$$

Table I. Main characteristics at baseline (mean ± *s*).

Characteristics	Men ($n = 64$)	Women ($n = 87$)	Total ($n = 151$)
Age (years)	59.0 ± 2.6	59.3 ± 2.6	59.2 ± 2.6
Body mass index (kg · m^{-2})	27.0 ± 3.4	26.6 ± 3.5	26.8 ± 3.4
Body fat (%)	25.0 ± 5.4	38.1 ± 5.4	32.5 ± 5.4

Table II. Mean heart rates (beats · min^{-1}) per walking speed from T0 to T4 (mean ± *s*; number of participants in parentheses).

	T0	T1	T2	T3	T4
HR_4	105 ± 15.0 (122)	104 ± 15.0 (133)	99.9 ± 15.3 (72)	101 ± 15.2 (49)	102 ± 15.3 (22)
HR_5	118 ± 17.6 (122)	115 ± 17.2 (132)	111 ± 17.9 (72)	112 ± 17.2 (49)	113 ± 18.6 (22)
HR_6	135 ± 19.3 (94)	131 ± 17.6 (118)	125 ± 20.2 (63)	125 ± 19.0 (43)	128 ± 20.4 (22)
HR_7	155 ± 15.5 (46)	148 ± 15.0 (63)	144 ± 20.2 (38)	143 ± 20.2 (29)	147 ± 21.4 (17)

Note: T0–T4: baseline to fourth follow-up measurement; HR_4–HR_7: heart rate at walking speeds of 4 to 7 km · h^{-1}.

Table III. Growth (model 1) and final multi-level (model 2) models per walking speed.

Walking speed 4 km · h^{-1}	Model 1			Model 2		
Fixed effects	Coefficient	SE[a]	*P*-value[b]	Coefficient	SE[a]	*P*-value[b]
Constant	104.69	1.22		107.45	1.56	
Time[c] (0–4)	−1.25	0.42	<0.01	−1.21	0.46	<0.01
Sex[d] (0–1)				−12.63	2.04	<0.001
BMI[e] (kg · m^{-2})				0.85	0.28	<0.01
$EE_{RECSPORT}$[f] (kcal · week^{-1})				0.00041	0.00056	N.S.
EE_{LTPA}[g] (kcal · week^{-1})				0.00032	0.00026	N.S.
Random effects	Variance			Variance		
Between individuals	156.37			115.75		
Within individuals	73.63			71.39		
Deviance	3116.75			2922.99		

Walking speed 5 km · h^{-1}	Model 1			Model 2		
Fixed effects	Coefficient	SE	*P*-value	Coefficient	SE	*P*-value
Constant	117.36	1.41		121.61	1.74	
Time[c] (0–4)	−1.65	0.46	<0.001	−1.61	0.51	<0.001
Sex[d] (0–1)				−16.50	2.27	<0.001
BMI[e] (kg · m^{-2})				1.05	0.31	<0.001
$EE_{RECSPORT}$[f] (kcal · week^{-1})				0.00042	0.00062	N.S.
EE_{LTPA}[g] (kcal · week^{-1})				0.00024	0.00029	N.S.
Random effects	Variance			Variance		
Between individuals	214.60			143.47		
Within individuals	91.38			87.84		
Deviance	3207.12			2994.18		

Walking speed 6 km · h^{-1}	Model 1			Model 2		
Fixed effects	Coefficient	SE	*P*-value	Coefficient	SE	*P*-value
Constant	134.17	1.62		140.10	2.04	
Time[c] (0–4)	−2.61	0.53	<0.001	−2.45	0.58	<0.001
Sex[d] (0–1)				−18.76	2.57	<0.001
BMI[e] (kg · m^{-2})				0.97	0.38	<0.05
$EE_{RECSPORT}$[f] (kcal · week^{-1})				0.00063	0.00068	N.S.
EE_{LTPA}[g] (kcal · week^{-1})				0.00025	0.00034	N.S.
Random effects	Variance			Variance		
Between individuals	251.29			167.81		
Within individuals	99.13			93.97		
Deviance	2781.16			2569.50		

Walking speed 7 km · h^{-1}	Model 1			Model 2		
Fixed effects	Coefficient	SE	*P*-value	Coefficient	SE	*P*-value
Constant	153.54	2.02		162.78	2.91	
Time[c] (0–4)	−3.08	0.77	<0.001	−3.40	0.85	<0.001
Sex[d] (0–1)				−17.43	3.22	<0.001
BMI[e] (kg · m^{-2})				0.74	0.49	N.S.
$EE_{RECSPORT}$[f] (kcal · week^{-1})				−0.00024	0.00092	N.S.
EE_{LTPA}[g] (kcal · week^{-1})				0.0011	0.00045	<0.01
Random effects	Variance			Variance		
Between individuals	160.74			97.74		
Within individuals	129.09			121.41		
Deviance	1584.90			1430.08		

[a]SE: standard error; [b]N.S. = not significant, $P > 0.05$; [c]Time: baseline = 0, T1 after 6 months = 1, T2 after 12 months = 2, T3 after 18 months = 3, T4 after 24 months = 4; [d]sex: women = 0, men = 1; [e]BMI = body mass index centred at a value of 25 kg · m^{-2}; [f]$EE_{RECSPORT}$ = energy expenditure for recreational sports activities; [g]EE_{LTPA} = energy expenditure for leisure-time physical activities.

With these equations the development of mean heart rate (HR) per walking speed over time could be predicted when the variables time (0–4, baseline to fourth follow-up measurement), sex (0 = women, 1 = men), and BMI were available. The numbers between brackets were the accessory standard errors, and BMI was centred at a value of 25 $kg \cdot m^{-2}$. The development of these predicted mean heart rates over time per walking speed is illustrated in Figures 1a to 1d. From baseline to T4, decreases in predicted mean heart rate were 5.5, 6.0, 10.0, and 9.0 $beats \cdot min^{-1}$ at walking speeds of 4, 5, 6, and 7 $km \cdot h^{-1}$, respectively. The relative decreases were 5.2, 5.1, 7.4, and 5.8% at speeds of 4, 5, 6, and 7, $km \cdot h^{-1}$, respectively.

Finally, subgroup analyses were conducted to establish if there were differences between participants who were fitter and made it to the highest walking speed (7 $km \cdot h^{-1}$) and participants who had to stop at lower walking speeds at baseline. In this way, two groups were formed: (1) a group consisting of 46 participants who completed the highest walking speed at baseline, and (2) a group of 76 participants who did not finish the highest walking speed of 7 $km \cdot h^{-1}$ at baseline. After adding this variable to the final multi-level model, no significant differences were observed between the two groups at walking speeds of 4, 5, and 6 $km \cdot h^{-1}$ (P-values > 0.05).

Discussion

This study was conducted in an attempt to determine whether a versatile physical activity intervention like the Groningen Active Living Model recreational sports programme can effectively improve cardiovascular function. The present results demonstrate a

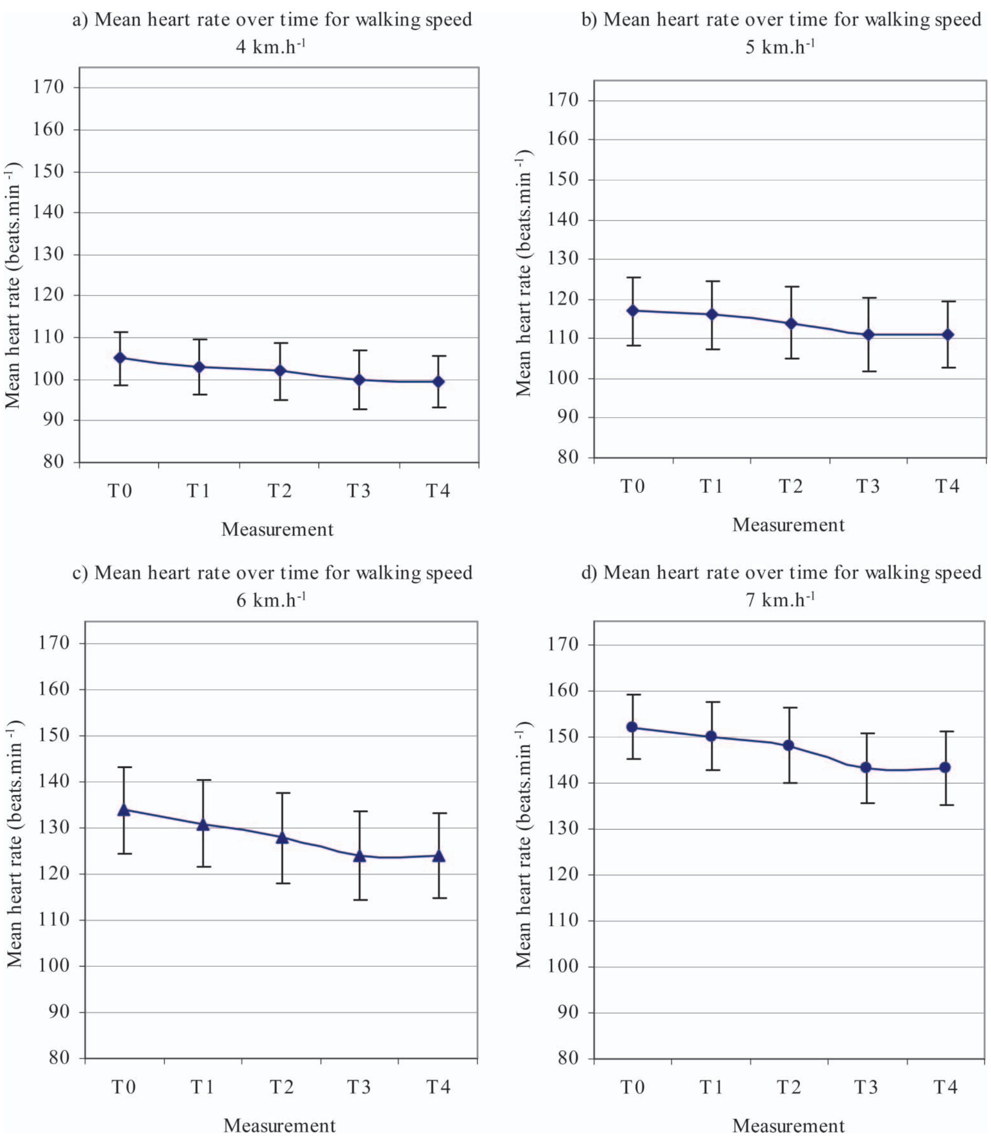

Figure 1. Predicted mean heart rate per walking speed over time.

significant decrease in heart rate during submaximal exercise over 18 months of participation in the programme.

The observed decrease in heart rate during submaximal exercise is not only significant but also meaningful. Lamberts and colleagues (Lamberts, Lemmink, Durandt, & Lambert, 2004) reported the natural variation in heart rate during submaximal exercise, with a standard error of measurement of submaximal heart rate at 1.1–1.4%. The relative changes in heart rate from baseline to T4 in our study ranged from 5.1% to 7.4%; this clearly is higher than the range in standard error reported by Lamberts et al. (2004) and could be considered beyond the natural variation for that variable. However, comparison between the two studies should be made with caution, since the study of Lamberts et al. was based on a younger population.

In addition, it is important to note some limitations of the present study. First, we did not include a control group, so results must be interpreted with caution. Second, we did not succeed in measuring resting heart rate. Many studies have reported adaptations in resting heart rate. Thus, information on changes in resting heart rate during participation in the GALM recreational sports programme would have been valuable. Before starting the walking test, participants were asked to sit still for 5 min and not touch the heart rate transmitter that was attached via a chest strap. Many participants in this community-based programme did not follow the instructions, however, resulting in a lack of standardization of resting heart rate. Consequently, these data were not considered reliable and thus excluded from further analysis. Finally, not all participants had data for all measurements over time, which would have strengthened the results of this study. To that end, multi-level modelling was used. In longitudinal community-based studies with missing data at different moments in time, multi-level modelling is a good way of treating such unbalanced data structures and making full use of all available data, with participants with few measurements adding only little to the final results (Snijders & Bosker, 1999).

Although the GALM recreational sports programme is not a high-intensity endurance-based exercise programme, a significant decrease in heart rate during submaximal exercise was observed. The magnitude of training effects depends on frequency of training, type and duration of activity, and, most important, intensity of the activity performed. A previous study that evaluated the intensity of the GALM recreational sports programme demonstrated that the overall mean intensity was 73.7% of predicted maximum heart rate (De Jong et al., 2005; Inbar et al., 1994), which places the programme within the intensity guidelines recommended to enhance aerobic fitness (ACSM, 1998a, 1998b). The intensity of the GALM recreational sports programme combined with the fact that persons with the lowest fitness had ample room to improve by doing more activity could explain the reported decline in heart rate at a slower speed relative to higher-intensity programmes meeting all endurance training guidelines (Pate et al., 1995).

Furthermore, the results of the GALM programme are in line with studies by Carter and colleagues (Carter, Banister, & Blaber, 2003) and Belman & Geasser (1991). Carter et al. (2003) found a reduction in heart rate during submaximal exercise of 8.1 ± 0.67 beats $\cdot$ min^{-1} or 6% after endurance training. Belman and Geasser (1991) found a comparable training-induced reduction in heart rate of 8 beats $\cdot$ min^{-1} at a submaximal power output after 8 weeks of lower-intensity exercise training (30 min walking at 50% $\dot{V}O_{2max}$ four times a week). From both studies it can be concluded that the GALM programme elicits an equal increase in cardiovascular function as endurance training programmes. A point of discussion is the adaptation time, since the endurance programme sessions of Carter et al. (2003) and Belman and Geasser (1991) were performed over 12 and 8 weeks, respectively, whereas comparable changes in the GALM participants took 12–18 months.

The graphics illustrating predicted mean heart rate at different walking speeds over time demonstrate a rapid decrease in predicted mean heart rate at the beginning and a plateau later on. Such a pattern might mean that the GALM recreational sports programme provided a sufficient training load during the first 12 months but not after that. A potential suggestion concerns promoting overload, and thus heart rate-related benefits, by increasing the frequency, duration, and intensity of the GALM sessions after 12 months of participation.

The covariates of sex and BMI were significantly related to heart rate at all walking speeds, except for BMI at 7 km $\cdot$ h^{-1}. No interactions were found for sex $\times$ time or BMI $\times$ time, implying that women and participants with a higher BMI show lower changes in heart rate at all walking speeds; however, this does not demonstrate different changes over time compared with men and people with a lower BMI. Other researchers have also reported a significant influence of sex and BMI on walking performance (Kline et al., 1987; Oja, Laukkanen, Pasanen, Tyry, & Vuori, 1991).

Contrary to our expectations, no significant links between heart rate changes and energy expenditure for recreational sports activities or energy expenditure for leisure-time physical activities over time were observed, except for energy expenditure for leisure-time physical activities at the highest walking speed (i.e. 7 $km \cdot h^{-1}$). A possible explanation is the wide range of self-reported physical activity for recreational sports activities (0–6848 $kcal \cdot week^{-1}$), especially leisure-time physical activities (0–18,560 $kcal \cdot week^{-1}$). Consequently, changes in heart rate that might normally be statistically significantly related to energy expenditure for physical activity potentially vanished because of the broad variation in both energy expenditure measures. Another explanation could be the misclassification of activities on the Voorrips physical activity questionnaire concerning walking and cycling for transportation versus recreational sports activities. Alternatively, the chosen physical activity questionnaire might not have been accurate enough in relation to the number of participants included. For future investigations of the same size, in line with findings and conclusions from other studies, use of a more objective way of measuring energy expenditure for physical activity (e.g. accelerometers) is recommended (Janz, 2006).

Conclusion

In conclusion, our results demonstrate that long-term participation (18 months) in the Groningen Active Living Model recreational sports programme significantly decreases heart rate during submaximal exercise, implying an increase in cardiovascular function of sedentary and underactive older adults aged 55–65 years. This increase in cardiovascular function is comparable with that in other training programmes. The results show that the GALM recreational sports programme, which is primarily based on an evolutionary-biological play theory and insights from social cognitive theory, is as effective in improving cardiovascular function as programmes that are primarily based on training principles (intensity, frequency, and duration).

Since this study was conducted in a real community setting, the results are relevant from a public health perspective. From research into the effectiveness of the recruitment strategy of the Groningen Active Living Model, we know that five percent (5.4%) of the GALM participants fit within the precontemplation phase and 74% of the participants in the contemplation/preparation phase as measured with the Dutch version of the Stages of Change Questionnaire at the start of the programme (Stevens et al., 2008). In addition, a comparison between the GALM participants' fitness and normative data for an average group of Dutch adults aged 55–65 years revealed that participants scored on average below mean values of the normative dataset, which underlines that they are less fit (De Jong et al., 2006). From the literature it is known that people with low fitness and poor health can gain most from a small increase in physical activity (Blair, Cheng, & Holder 2001; Pate et al., 1995). Hence from a public health perspective it can be concluded that participation in the Groningen Active Living Model can have a potentially significant impact on the fitness and health of sedentary and underactive older adults.

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