Lipid profile in men and women with different levels of sports participation and physical activity

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Abstract

Objective: The purpose of the present study was to analyse the lipid profile in men and women differentiated according to energy expenditure during sports participation (EE_{SPORT}), energy expenditure during active leisure time (EE_{ALT}) and overall energy expenditure (EE_{TOTAL}).

Design: The subjects were grouped by sex, age, EE_{SPORT}, EE_{ALT} and EE_{TOTAL}. Group differences were analysed using analyses of covariance with BMI and alcohol consumption as covariates.

Setting: Physical activity was assessed using the Flemish Physical Activity Computerised Questionnaire. Fasting blood samples were taken to measure total cholesterol (TC), TAG, HDL-cholesterol (HDL-C), LDL-cholesterol (LDL-C) and the ratio TC:HDL-C.

Subjects: The study sample consisted of 1170 Flemish men and women between 18 and 75 years of age.

Results: Differences in lipid profile were observed in the younger age group (<45 years), all in favour of the most active group. More specifically, when differentiating by EE_{ALT} and EE_{TOTAL}, men had a healthier lipid profile for TAG, HDL-C and TC:HDL-C. Differentiation according to EE_{SPORT} revealed the same significant results except for TAG. In women significant results for HDL-C, LDL-C and TC:HDL-C were found when differentiated by EE_{SPORT}.

Conclusions: Men and women <45 years of age with higher levels of energy expenditure due to sport show a better lipid profile than their sedentary counterparts. When differentiating subjects according to energy expenditure during active leisure time or overall energy expenditure, only in men was a healthier lipid profile observed in favour of the most active subjects.

Plasma lipoproteins play a major role in the aetiology of atherosclerosis and CVD[1,2], which continue to be the leading cause of morbidity and mortality in the industrialised world[3].

It has been well documented that a variety of personal characteristics and environmental factors influence the composition of plasma lipids and lipoproteins, including age, gender and the associated hormonal changes in women, genetics, BMI, body weight, body composition, alcohol consumption, smoking behaviour and medication use[1,4–10].

In addition, it has been shown that physical activity can affect the plasma lipid profile. Most studies indicate that regular exercise produces favourable changes in plasma lipids and lipoproteins[11–21].

Evidence from epidemiological and training studies indicates that those who are physically active exhibit higher levels of HDL-cholesterol (HDL-C)[6,7,18,22–30], lower levels of TAG and a lower ratio of total cholesterol (TC) to HDL-C than those who are less active[11,12,14–16,19,21,31,32]. Durstine *et al.*[33] reviewed the literature and concluded that regular exercise can raise HDL-C levels by 2–8 mg/dl and lower TAG by 5–38 mg/dl in men and women.

The preceding results indicate that physical activity can positively affect the lipid profile. However, some investigators have failed to find a significant association between physical activity and favourable changes in the lipid profile[34–36]. These discrepancies probably reflect

the differences in the literature concerning intensity of the physical activity or energy expenditure due to physical activity. Many investigators agree that an exercise threshold needs to be met before favourable changes in HDL-C can occur[13,17,24,27,33]. For most individuals, this threshold is associated with a physical activity-related energy expenditure of 5·02 MJ (1200 kcal)[12] or 8 MJ or more[13] per week, or an intensity of 29·3 kJ/min (7 kcal/min)[17], or 5–6 METs (metabolic energy equivalent tasks)[15].

Concerning the effect of exercise on TC and LDL-cholesterol (LDL-C) there is inconclusive evidence in both epidemiological and training studies. A careful evaluation of the literature indicates that exercise training seldom alters TC and LDL-C[12,14]. However, there are a few exceptions. In a meta-analysis of randomised controlled trials, it was concluded that walking results in decreases in LDL-C[37].

Obviously it is not completely clear whether in a normal population it should be advised to augment energy expenditure by high-intensity activities (sport) or by being more physically active in general, in order to obtain a healthier lipid profile. Moreover, relatively few studies have included women and their conclusions are less consistent than in men.

Therefore, the purpose of the current study was to investigate the lipid profile in a general population of Flemish males and females differentiated according to sports-related energy expenditure, energy expenditure during active leisure time and total energy expenditure.

Methods

Subjects

The subjects included in the present study originate from the Policy Research Centre Sport, Physical Activity and Health. This Policy Research Centre was established to investigate physical fitness, physical activity and sports participation in relation to health in the Flemish population. In order to fulfil this aim, almost 6000 subjects between 18 and 75 years of age were tested in their home town (Theme 1), of which almost 2000 subjects also completed an extensive test battery in the central laboratory of the Policy Research Centre (Theme 2).

For the present study, the data of subjects originating from Theme 2 were used. Of the total sample of almost 2000 subjects, 1632 had complete data on blood lipids, dietary intakes and physical activity habits. It was decided to exclude students, pensioners older than 75 years of age and those who took cholesterol-lowering medication. Thus, a total of 1170 subjects (672 men, mean age 46·30 (sd 10·67) years and 498 women, mean age 44·38 (sd 8·98) years) were included in the present study.

Assessment of physical activity

Participation in sport and physical activity was investigated using the Flemish Physical Activity Computerised Questionnaire (FPACQ), which is extensively described by Matton et al.[38].

In this questionnaire subjects were asked to select a maximum of three of their most important sports out of a list of 196 specific sports. To calculate the hours of health-related sports participation, the sum was made of the hours per week they spent on these three sports. This value could amount to a maximum of 30 h. Sports participation was considered as health-related sports participation if the associated MET value[39] of the sport was at least 4·5, 4·0 and 3·5 respectively for subjects younger than 35, between 35 and 49 and older than 50 years of age. For each sport, the MET value was multiplied by the time spent on this sport. The sum of these three multiplications results in the total energy expenditure during health-related sports participation and was called EE_{SPORT} (MET × h/week).

Furthermore, subjects were asked about time spent on active transportation (walking and cycling) in leisure time and time spent on light, moderate and vigorous household and garden activities. For each active leisure-time activity, the MET value was multiplied by the time spent on this activity. The sum of these multiplications plus the energy expenditure during health-related sports participation resulted in EE_{ALT} (MET × h/week), an indication of the overall energy expenditure of active leisure-time activities.

Finally, total energy expenditure, EE_{TOTAL} (MET × h/week), was calculated by summing the energy expenditure of all activities during a usual week.

Assessment of dietary intake

Dietary habits and energy intake were assessed by means of the 3 d (two weekdays and one weekend day) food record method. The subjects were asked to write down all the food and drinks they consumed during those three days. The detailed list of dietary products was processed with the BECEL computer program version 5·0 (Hartog-Union and Van den Bergh, Rotterdam, The Netherlands). To control for confounding factors the relationship between dietary intake and lipid profile was analysed by correlation and regression analyses (results not shown). Based on these analyses it was decided to use alcohol consumption as covariate.

Lipid analysis

Fasting blood samples (after an overnight fast) were taken for the measurement of TC, TAG, HDL-C, LDL-C and TC:HDL-C ratio. The blood lipids and lipoproteins were measured on an Olympus AU5400 analyser (Olympus Diagnostica, Hamburg, Germany). The CV between days were 2·0 % (at 7·02 mmol/l) for TC, 1·4 % (at 2·07 mmol/l)

for TAG, 3·9 % (at 2·04 mmol/l) for HDL-C and 3·4 % (at 4·02 mmol/l) for LDL-C.

Statistical analysis

The subjects were grouped by sex, age (<45 years, ≥45 to <55 years and ≥55 years), EE_{SPORT}, EE_{ALT} and EE_{TOTAL} (<25th percentile *v.* >75th percentile). Descriptive statistics (mean, SD, P25 and P75) were calculated for the anthropometric characteristics, physical activity variables and the serum lipid and lipoprotein values. Group differences were analysed by analyses of covariance with BMI and alcohol consumption as covariates since prior analyses (correlation and regression analyses) showed the importance of these factors (results not shown).

All statistical analyses were performed using the Statistical Analysis Systems statistical software package version 9·1 (SAS Institute, Cary, NC, USA). Statistical significance was set at $\alpha = 0.05$.

Results

Descriptive statistics of the anthropometric characteristics, physical activity-related variables, and the serum lipid and lipoprotein values are presented in Tables 1 and 2 for men and women respectively.

Analyses of covariance in the younger age group differentiated according to sex and level of energy expenditure (EE_{SPORT}, EE_{ALT} or EE_{TOTAL}) revealed significant differences in lipid profile, all in favour of the most active groups (Tables 3 and 4).

Concerning the comparison of young men with different levels of EE_{SPORT} (<P25 *v.* >P75), significant results were found for HDL-C (1·37 (SD 0·30) mmol/l *v.* 1·49 (SD 0·30) mmol/l) and TC:HDL-C (3·96 (SD 0·88) *v.* 3·54 (SD 0·88); Table 3). For the young women, significant results were observed for HDL-C (1·65 (SD 0·35) mmol/l *v.* 1·76 (SD 0·34) mmol/l), LDL-C (3·09 (SD 0·78) mmol/l *v.* 2·76 (SD 0·78) mmol/l) and TC:HDL-C (3·29 (SD 0·78) *v.* 2·95 (sd 0·71); Table 4).

Differentiation according to EE_{ALT} and EE_{TOTAL} in young men revealed significant differences for TAG (respectively 1·20 (SD 0·49) mmol/l *v.* 1·04 (SD 0·49) mmol/l and 1·22 (SD 0·52) mmol/l *v.* 1·04 (SD 0·51) mmol/l), HDL-C (respectively 1·30 (SD 0·25) mmol/l *v.* 1·50 (SD 0·25) mmol/l and 1·31 (SD 0·27) mmol/l *v.* 1·48 (SD 0·27) mmol/l) and TC:HDL-C (respectively 4·09 (SD 0·79) *v.* 3·53 (SD 0·79) and 4·07 (SD 0·88) *v.* 3·58 (SD 0·88); Table 3). In young women no significant differences could be observed.

In the middle-aged group (≥45 to <55 years) differentiated according to sex and level of energy expenditure (EE_{SPORT}, EE_{ALT}, EE_{TOTAL}), no significant differences were observed except for HDL-C in men grouped by EE_{SPORT} (1·39 (SD 0·30) mmol/l *v.* 1·53 (SD 0·29) mmol/l; Table 3).

Comparison of the older age group (≥55 years) differentiated according to sex and level of energy expenditure (EE_{SPORT}, EE_{ALT}, EE_{TOTAL}) did not reveal any significant difference except for TAG in men grouped by EE_{ALT} (1·51 (SD 0·55) mmol/l *v.* 1·23 (SD 0·55) mmol/l; Table 3).

Discussion

There is consolidated evidence that physical activity exerts beneficial effects on lipid profiles. Former studies focused on the importance of the intensity of physical activity whereas more recently focus has shifted towards energy expenditure. Durstine *et al.*[33] concluded in their review that the effects of exercise on lipid and lipoprotein levels can be initiated at low training volumes and will continue in a dose–response fashion with increasing training volume. However, results are not equivocal in different age groups. Moreover, studies focusing on women often show conflicting results and are rather sparse.

Obviously debate continues regarding the effect of physical activity. The purpose of the present study was to investigate the importance of energy expenditure on the lipid profile in a general population of Flemish males and females of different age groups. More specifically, it was investigated whether energy expenditure in general or sports-related energy expenditure contributes to a healthier lipid profile.

The results of this study indicate that young women (<45 years) of the highest quartile of energy expenditure during health-related sports participation have healthier values for HDL-C, LDL-C and TC:HDL-C than their inactive counterparts. It was expected to find differences regarding HDL-C[6,7,24,25,27–29,33,40], but finding differences in LDL-C was rather surprising since there is little support in the cross-sectional literature for significant differences in LDL-C between active and inactive groups. Even in training studies significant changes in LDL-C are generally not observed. However, there are a few exceptions: most frequently in studies with exercise training programmes in which participants expended more than 5·02 MJ/week (1200 kcal/week)[33]. Analysing the energy expenditure due to health-related sports participation of the women younger than 45 years of age, it was observed that none of the subjects of the group <P25 and seventy-six subjects of the seventy-eight subjects of the group >P75 had an EE_{SPORT} above 4·18 MJ/week (1000 kcal/week). Of these seventy-six subjects, sixty-four women had an EE_{SPORT} above 5·02 MJ/week (1200 kcal/week). It is clear that the energy expenditure due to sports participation in the most active young women of the present study is comparable with the energy expenditure in training studies in which significant effects of physical activity on the lipid profile were observed.

When the women younger than 45 years of age were differentiated according to energy spent during active

Table 1 Descriptive statistics (mean, SD, 25th percentile (P25) and 75th percentile (P75)) of the anthropometric characteristics, physical activity variables and serum lipid and lipoprotein values among men

	<45 years (n 310)				≥45 to <55 years (n 213)				≥55 years (n 149)			
	Mean	SD	P25	P75	Mean	SD	P25	P75	Mean	SD	P25	P75
Age (years)	37·6	5·9	35·0	42·3	47·8	2·1	46·6	48·4	62·1	4·9	58·0	65.7
Weight (kg)	79·8	11·5	71·9	85·9	80·7	9·9	73·9	86·1	79·6	10·1	75·2	85.6
BMI (kg/m²)	25·0	3·0	22·9	26·8	25·7	3·1	23·6	27·3	26·7	2·9	24·9	28.7
Health-related sports participation (h/week)	3·6	4·2	0·2	5·0	3·4	3·9	0·5	5·0	5·1	5·2	0·1	7.3
EE_{SPORT} (MET × h/week)	29·6	38·9	1·8	41·6	23·0	30·1	2·1	29·6	28·4	36·4	0·5	40.0
EE_{ALT} (MET × h/week)	70·7	47·3	38·3	87·3	65·7	42·2	34·5	83·3	93·2	52·9	51·4	123.7
EE_{TOTAL} (MET × h/week)	312·6	45·3	280·0	334·7	301·7	37·1	276·1	322·5	285·3	40·3	256·6	302.0
TC (mmol/l)	5·26	1·05	4·45	5·98	5·54	0·99	4·84	6·19	5·64	0·80	5·15	6.11
TAG (mmol/l)	1·19	0·62	0·75	1·49	1·37	0·74	0·92	1·67	1·26	0·55	0·87	1.50
HDL-C (mmol/l)	1·40	0·31	1·19	1·58	1·45	0·31	1·22	1·63	1·50	0·33	1·24	1.71
LDL-C (mmol/l)	3·30	0·94	2·67	3·96	3·46	0·92	2·82	3·99	3·55	0·73	3·03	3.99
TC:HDL-C	3·90	1·03	3·14	4·56	4·01	1·14	3·25	4·67	3·92	0·96	3·14	4.64

EE_{SPORT}, energy expenditure during health-related sports participation; EE_{ALT}, energy expenditure during active leisure time; EE_{TOTAL}, total energy expenditure; TC, total cholesterol; HDL-C, HDL-cholesterol; LDL-C, LDL-cholesterol.

Table 2 Descriptive statistics (mean, SD, 25th percentile (P25) and 75th percentile (P75)) of the anthropometric characteristics, physical activity variables and serum lipid and lipoprotein values among women

	<45 years (n 306)				≥45 to <55 years (n 123)				≥55 years (n 69)			
	Mean	SD	P25	P75	Mean	SD	P25	P75	Mean	SD	P25	P75
Age (years)	38·9	4·8	37·5	41·7	48·9	2·9	46·3	51·0	60·9	4·3	57·3	64.2
Weight (kg)	65·5	10·1	59·1	70·5	66·1	11·8	57·8	72·0	65·1	10·0	57·3	72.2
BMI (kg/m²)	23·8	3·6	21·5	25·4	24·6	4·2	21·8	26·4	25·1	3·7	22·8	26.9
Health-related sports participation (h/week)	1·8	2·3	0·0	2·8	2·4	3·1	0·0	3·0	3·6	3·7	0·5	5.5
EE_{SPORT} (MET × h/week)	11·8	18·0	0·0	17·0	12·3	14·5	0·0	17·7	15·8	16·7	1·6	23.0
EE_{ALT} (MET × h/week)	68·5	30·7	46·7	83·9	72·2	36·1	45·7	91·6	86·3	40·6	56·9	108.1
EE_{TOTAL} (MET × h/week)	286·4	27·9	268·4	299·2	282·2	23·5	265·0	300·0	272·9	26·4	257·0	282.7
TC (mmol/l)	5·08	0·84	4·45	5·59	5·44	0·94	5·00	6·01	6·10	1·09	5·36	6.81
TAG (mmol/l)	0·98	0·41	0·69	1·19	1·12	0·45	0·77	1·38	1·22	0·58	0·81	1.42
HDL-C (mmol/l)	1·71	0·37	1·45	1·94	1·86	0·47	1·53	2·15	1·76	0·42	1·45	1.97
LDL-C (mmol/l)	2·91	0·77	2·38	3·44	3·06	0·83	2·59	3·65	3·78	1·00	3·06	4.30
TC:HDL-C	3·09	0·75	2·56	3·46	3·10	0·90	2·48	3·44	3·65	1·13	2·97	4.00

EE_{SPORT}, energy expenditure during health-related sports participation; EE_{ALT}, energy expenditure during active leisure time; EE_{TOTAL}, total energy expenditure; TC, total cholesterol; HDL-C, HDL-cholesterol; LDL-C, LDL-cholesterol.

leisure time or overall energy expenditure during a normal week, significant differences were no longer observed. Weller and Corey[41] showed that physical activity was inversely associated with risk of death in women and pointed out that the contribution of non-leisure (household chores) energy expenditure represented, on average, 82 % of women's total activity. They argued that when studying the effect of physical activity on CVD in women non-leisure energy expenditure should be taken into account. The results of the present study suggest that sports-related energy expenditure, rather than active leisure time-related energy expenditure in which household activities are included, results in a healthy lipid profile. This conclusion is supported by the findings of O'Connor et al.[42], who stated that moderate to vigorous sporting activity was directly related to high HDL-C whereas total energy expenditure was uncorrelated with blood lipids. To illustrate: in the present study, less than half of the young women who belonged to the group >P75 differentiated according to energy spent

during active leisure time had an EE_{SPORT} above 5·02 MJ/week (1200 kcal/week). So it seems that a minimum intensity threshold has to be met.

In young men differentiated according to energy expenditure during health-related sports participation significant results were observed for HDL-C and TC:HDL-C. No significant results were observed for TAG. This finding was unexpected since it was argued by Durstine et al.[33] that both HDL-C and TAG levels can be changed by similar training volumes. They concluded that training volumes that elicit energy expenditures ≥5·02 MJ/week (≥1200 kcal/week) are associated with elevations in HDL-C levels and reduced TAG levels. When the men younger than 45 years of age were differentiated according to EE_{ALT} or EE_{TOTAL}, significant differences were observed for HDL-C, TC:HDL-C and also for TAG.

Analysing EE_{SPORT} in the group >P75 differentiated according to EE_{SPORT}, it was observed that all seventy-eight subjects had values exceeding the threshold of 5·02 MJ/week (1200 kcal/week). When differentiating

Table 3 Comparison of serum lipid and lipoprotein values between men being part of the lowest and highest quartile of energy spent during health-related sports participation, energy spent during active leisure time and total energy spent during a week: analyses of covariance with BMI and alcohol consumption as covariates

	Men <45 years									Men ≥45 to <55 years									Men ≥55 years								
	EE$_{SPORT}$ <P25 (n 77)		EE$_{SPORT}$ >P75 (n 78)			EE$_{SPORT}$ <P25 (n 54)		EE$_{SPORT}$ >P75 (n 54)			EE$_{SPORT}$ <P25 (n 38)		EE$_{SPORT}$ >P75 (n 38)		
	LSMean	SD	LSMean	SD	P	LSMean	SD	LSMean	SD	P	LSMean	SD	LSMean	SD	P
TC (mmol/l)	5·18	1·02	5·12	1·01	0·718	5·53	1·03	5·57	1·01	0·837	5·67	0·80	5·75	0·80	0·643
TAG (mmol/l)	1·16	0·55	1·09	0·55	0·437	1·43	0·71	1·22	0·71	0·138	1·32	0·55	1·17	0·55	0·243
HDL-C (mmol/l)	1·37	0·30	1·49	0·30	**0·012**	1·39	0·30	1·53	0·29	**0·014**	1·48	0·32	1·60	0·32	0·130
LDL-C (mmol/l)	3·27	0·91	3·12	0·91	0·334	3·48	0·97	3·47	0·95	0·957	3·57	0·70	3·61	0·70	0·802
TC:HDL-C	3·96	0·88	3·54	0·88	**0·006**	4·21	1·10	3·82	1·10	0·074	3·98	0·86	3·77	0·86	0·308
	EE$_{ALT}$ <P25 (n 78)		EE$_{ALT}$ >P75 (n 78)			EE$_{ALT}$ <P25 (n 53)		EE$_{ALT}$ >P75 (n 53)			EE$_{ALT}$ <P25 (n 37)		EE$_{ALT}$ >P75 (n 37)		
	LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD	
TC (mmol/l)	5·15	0·91	5·13	0·91	0·888	5·35	0·92	5·66	0·92	0·090	5·62	0·74	5·74	0·74	0·500
TAG (mmol/l)	1·20	0·49	1·04	0·49	**0·036**	1·33	0·68	1·38	0·67	0·718	1·51	0·55	1·23	0·55	**0·036**
HDL-C (mmol/l)	1·30	0·25	1·50	0·25	**<0·001**	1·40	0·28	1·49	0·28	0·081	1·43	0·28	1·48	0·28	0·468
LDL-C (mmol/l)	3·29	0·85	3·15	0·85	0·295	3·33	0·87	3·52	0·85	0·263	3·49	0·69	3·69	0·69	0·240
TC:HDL-C	4·09	0·79	3·53	0·79	**<0·001**	3·95	0·87	3·97	0·87	0·908	4·12	0·91	4·04	0·91	0·726
	EE$_{TOTAL}$ <P25 (n 77)		EE$_{TOTAL}$ >P75 (n 78)			EE$_{TOTAL}$ <P25 (n 54)		EE$_{TOTAL}$ >P75 (n 53)			EE$_{TOTAL}$ <P25 (n 38)		EE$_{TOTAL}$ >P75 (n 37)		
	LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD	
TC (mmol/l)	5·11	0·89	5·12	0·89	0·975	5·52	0·91	5·38	0·92	0·437	5·68	0·75	5·71	0·76	0·832
TAG (mmol/l)	1·22	0·52	1·04	0·51	**0·028**	1·39	0·66	1·21	0·67	0·171	1·29	0·56	1·18	0·56	0·422
HDL-C (mmol/l)	1·31	0·27	1·48	0·27	**<0·001**	1·41	0·29	1·48	0·30	0·245	1·53	0·34	1·60	0·33	0·362
LDL-C (mmol/l)	3·23	0·80	3·15	0·80	0·512	3·47	0·82	3·34	0·83	0·436	3·55	0·72	3·56	0·72	0·931
TC:HDL-C	4·07	0·88	3·58	0·88	**<0·001**	4·05	0·88	3·81	0·87	0·152	3·91	0·92	3·73	0·91	0·399

EE$_{SPORT}$, energy expenditure during health-related sports participation; EE$_{ALT}$, energy expenditure during active leisure time; EE$_{TOTAL}$, total energy expenditure; LSMean, least-squares mean; TC, total cholesterol; HDL-C, HDL-cholesterol; LDL-C, LDL-cholesterol.

Table 4 Comparison of serum lipid and lipoprotein values between women being part of the lowest and highest quartile of energy spent during health-related sports participation, energy spent during active leisure time and total energy spent during a week: analyses of covariance with BMI and alcohol consumption as covariates

	Women <45 years					Women ≥45 to <55 years					Women ≥55 years				
	EE_{SPORT} <P25 (n 94)		EE_{SPORT} >P75 (n 78)			EE_{SPORT} <P25 (n 33)		EE_{SPORT} >P75 (n 30)			EE_{SPORT} <P25 (n 17)		EE_{SPORT} >P75 (n 18)		
	LSMean	SD	LSMean	SD	P	LSMean	SD	LSMean	SD	P	LSMean	SD	LSMean	SD	P
TC (mmol/l)	5·21	0·85	4·98	0·85	0·090	5·65	0·92	5·42	0·91	0·336	6·44	1·11	5·74	1·11	0·084
TAG (mmol/l)	1·00	0·39	0·98	0·39	0·854	1·26	0·46	1·07	0·46	0·132	1·26	0·63	1·46	0·63	0·375
HDL-C (mmol/l)	1·65	0·35	1·76	0·34	**0·048**	1·86	0·49	2·01	0·48	0·245	1·78	0·37	1·65	0·37	0·334
LDL-C (mmol/l)	3·09	0·78	2·76	0·78	**0·007**	3·23	0·77	2·91	0·77	0·122	4·07	0·96	3·41	0·96	0·061
TC:HDL-C	3·29	0·78	2·95	0·71	**0·004**	3·23	0·80	2·83	0·77	0·054	3·70	0·91	3·63	0·89	0·825
	EE_{ALT} <P25 (n 77)		EE_{ALT} >P75 (n 76)			EE_{ALT} <P25 (n 31)		EE_{ALT} >P75 (n 31)			EE_{ALT} <P25 (n 18)		EE_{ALT} >P75 (n 17)		
	LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD	
TC (mmol/l)	5·03	0·84	5·06	0·84	0·847	5·12	0·88	5·40	0·87	0·205	6·48	1·10	5·80	1·10	0·089
TAG (mmol/l)	1·03	0·43	0·96	0·42	0·279	0·98	0·40	1·09	0·40	0·282	1·32	0·53	1·10	0·53	0·249
HDL-C (mmol/l)	1·67	0·36	1·73	0·36	0·340	1·86	0·45	1·91	0·43	0·708	1·73	0·44	1·76	0·45	0·871
LDL-C (mmol/l)	2·87	0·77	2·88	0·77	0·968	2·79	0·76	2·99	0·75	0·326	4·14	1·01	3·54	1·00	0·096
TC:HDL-C	3·10	0·79	3·08	0·78	0·841	2·93	0·72	2·97	0·72	0·814	4·08	1·32	3·38	1·32	0·140
	EE_{TOTAL} <P25 (n 76)		EE_{TOTAL} >P75 (n 76)			EE_{TOTAL} <P25 (n 31)		EE_{TOTAL} >P75 (n 31)			EE_{TOTAL} <P25 (n 17)		EE_{TOTAL} >P75 (n 17)		
	LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD		LSMean	SD	LSMean	SD	
TC (mmol/l)	4·96	0·88	5·07	0·88	0·406	5·19	0·95	5·67	0·94	0·054	6·34	1·19	5·88	1·19	0·277
TAG (mmol/l)	0·98	0·38	0·93	0·38	0·392	1·13	0·47	1·09	0·47	0·750	1·21	0·51	1·02	0·51	0·306
HDL-C (mmol/l)	1·69	0·34	1·72	0·34	0·573	1·78	0·46	1·92	0·45	0·239	1·76	0·32	1·66	0·32	0·400
LDL-C (mmol/l)	2·81	0·81	2·92	0·81	0·391	2·89	0·81	3·24	0·79	0·094	4·02	1·07	3·74	1·07	0·458
TC:HDL-C	3·04	0·70	3·05	0·70	0·950	3·18	0·95	3·10	0·89	0·742	3·91	1·20	3·57	1·20	0·425

EE_{SPORT}, energy expenditure during health-related sports participation; EE_{ALT}, energy expenditure during active leisure time; EE_{TOTAL}, total energy expenditure; LSMean, least-squares mean; TC, total cholesterol; HDL-C, HDL-cholesterol; LDL-C, LDL-cholesterol.

according to EE_{ALT} or EE_{TOTAL} most of the subjects belonging to the group >P75 still had EE_{SPORT} values above 5·02 MJ/week (1200 kcal/week; this in contrast to the young women). However, when looking at the mean and SD of energy spent during active leisure time of the group <P25 differentiated according to EE_{ALT}, it becomes clear that these subjects were much less active [8·35 (SD 3·09) MJ/week (1996 (SD 739) kcal/week)] than the subjects belonging to the group <P25 differentiated according to EE_{SPORT} [14·69 (SD 9·47) MJ/week (3511 (SD 2263) kcal/week)]. For the group >P75, when differentiating according to EE_{ALT} higher values were observed for EE_{ALT} than for EE_{SPORT} when differentiating according to EE_{SPORT} [43·59 (SD 15·67) MJ/week (10 419 (SD 3745) kcal/week), with a minimum value of 24·33 MJ/week (5815 kcal/week) v. 39·05 (SD 17·98) MJ/week (9333 (SD 4297) kcal/week), with a minimum value of 15·89 MJ/week (3798 kcal/week)]. In contrast to the young women it seems that differentiating young men according to EE_{ALT} or EE_{TOTAL} results in more contrasting groups than when differentiating according to EE_{SPORT}.

In the middle-aged (≥45 to <55 years) and older age groups (≥55 years) no significant differences were observed except for HDL-C in middle-aged men grouped by EE_{SPORT} and TAG in men older than 55 years of age differentiated according to EE_{ALT}. However, several studies have shown the beneficial effect of physical activity on the lipid profile in middle-aged and older adults[8,10,15,21,22,26,37,43]. It has already been suggested that energy expenditure has to be above a certain threshold[33]. Fonong *et al.*[35] reported that short-time exercise training, generating less than 3·77 MJ/week (900 kcal/week) in exercise energy expenditure, fails to influence HDL-C levels in healthy older men and women. In the present study, when participants of the middle-aged and older age groups were differentiated according to EE_{SPORT}, none of the subjects belonging to the group <P25 and all of the subjects belonging to the group >P75 had an EE_{SPORT} exceeding 5·02 MJ/week (1200 kcal/week). It seems that the threshold suggested by Durstine *et al.*[33] does not elicit positive effects on the lipid profile in the present study sample older than 45 years of age.

It can be postulated that also an intensity threshold has to be met to expect significant effects on blood lipids. For most individuals, this threshold is associated with 5–6 METs[15,17]. Regarding this finding it can be argued that the criterion used to consider sports with an intensity of at least 3·5–4·0 METs (walking) as health-related sports participation in the older and middle-aged groups was rather low. However, former studies have shown that even walking has beneficial effects on the lipid profile and lowers the risk of coronary events, especially in older participants[37,43,44].

It should be mentioned that also in the present study BMI and alcohol consumption were observed to be important determinants of the lipid profile. It has previously been reported that greater weekly intakes of alcohol were associated with significantly higher HDL-C in both men and women[45]. Thus, alcohol is a potentially important confounder and studies which fail to take this factor into account may overestimate the contribution of physical activity to a healthy lipid profile. The same is true for BMI. A recent study showed that high BMI was more strongly related to adverse cardiovascular biomarker levels than physical inactivity. However, within BMI categories, physical activity was generally associated with more favourable cardiovascular biomarker levels than inactivity[46]. It is clear that studies focusing on the effect of physical activity on the lipid profile should take these determinants into account.

It can be concluded that young men and women with higher levels of energy expenditure due to sports activities show a better lipid profile than their sedentary counterparts. When differentiating subjects according to EE_{ALT} or EE_{TOTAL} only for the men could a healthier lipid profile be observed in favour of the most active subjects. It seems that, in the present study, taking household and garden activities into account to differentiate groups obscures differences in lipid profiles in women and amplifies differences in lipid profiles in men. For men and women younger than 45 years of age the conclusion of Durstine *et al.*[33], that training volumes eliciting energy expenditures ≥5·02 MJ/week (≥1200 kcal/week) contribute to a healthy lipid profile, can be confirmed.

In the middle-aged and older age groups differentiated according to energy expenditure (EE_{SPORT}, EE_{ALT} or EE_{TOTAL}), no differences could be observed in lipid profile except for HDL-C in middle-aged men grouped by EE_{SPORT} and TAG in older men grouped by EE_{ALT}.

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