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In search of lost time: When people start an exercise program, where does the time come from? A randomised controlled trial.

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Abstract

Background When people commence an exercise program, they need to find time from elsewhere in their time budgets to accommodate it. How people restructure these time budgets is likely to have flow-on health impacts.

Purpose The purpose of this study was to investigate changes in use of time when commencing a structured exercise program.

Design This study used a randomised, multi-arm, parallel controlled trial design. Participants were randomly assigned to one of three groups using a computer-generated allocation sequence. Participants in the *Moderate* group were prescribed an additional 150 minutes and the *Extensive* group an additional 300 minutes per week of moderate to vigorous physical activity (MVPA) for six weeks. Prescribed exercise was accumulated through both supervised group sessions and unsupervised individual sessions monitored by heart rate telemetry.

Setting/participants A total of 129 insufficiently active adults aged 18-60 years were recruited to participate in this study from January 2011 to February 2012 and analysis was conducted in May 2012.

Main outcome measure Use of time was determined using the Multimedia Activity Recall for Children and Adults, a computerised 24-hour recall instrument. Four days of recall was collected at baseline (zero weeks), mid- and end-intervention (three and six weeks). Daily minutes of activity in 11 activity domains and energy expenditure zones were calculated for analysis.

Results Relative to changes in the control group, daily time spent in overall MVPA (and its subcomponents, sport and exercise and active transport in particular) increased by 22-39 min/d in the intervention groups ($p<0.001$), and the time was drawn largely from time spent watching television (59-63 min/d) ($p=0.01$).

Conclusion This study is the first to comprehensively map changes in time use across an exercise program. The results suggest that exercise interventions should be mindful not only of compliance but of “ripple effects” in use of time.

1 Introduction

When people undertake a new exercise program, the time spent in other domains of life, such as sleep, screen time or leisure, must be reduced to accommodate the new activity. If someone starts jogging at lunchtime, for example, they will need to find time not only for the jogging, but also for changing into exercise clothes, showering and changing back into work clothes after the run. Where does this time come from? Which “time reservoirs” are drawn upon to be able to go jogging? How do people restructure their “time budgets” to incorporate a new exercise program?

Decisions about how to restructure time budgets to accommodate new physical activity (PA) can have important health consequences. If a new exerciser chooses to reduce their screen time, for example, then there will presumably be additional health benefits, given that sedentary time is a risk factor for all-cause mortality and cardiovascular disease independently of physical activity (1, 2). Conversely, if they choose to sleep less, the benefits of physical activity may be reduced. Shorter sleep duration has been associated with greater risk of obesity (3) and depression (4), though both of these health issues may also be mitigated by physical activity (5) (6). A further possibility is that a new exerciser will reduce physical activity in other domains, so that there will be no net increase in physical activity. This is the so-called “activitystat” hypothesis (7). For example, Mekary et al. (2008) longitudinally followed 4558 pre-menopausal US women for six years and found that changes in weight status depended not only on changes in their exercise patterns, but also on what that exercise displaced in the overall time budget. Women who increased their jogging by 30 min/d lost between 1.6 and 3.7 kg depending on which activities jogging displaced (8).

Clearly, in order to accurately assess the overall effects of physical activity interventions we should investigate both changes in physical activity and the "ripple effects" which potentially impact on health outcomes. Similarly, in order to distinguish true dose-response relationships, ripple effects must be measured and considered. To date, physical activity interventions (and other time-based behaviour change interventions) have generally employed either simple physical activity questionnaires, or wearable, objective 24 h monitoring devices, to assess the effects of their interventions. These methods lack the ability to capture the domain- and attribute-specific benefits of physical activity (9) and its flow-on effects. As noted by Mekary and Ding (2010), only via a time substitution approach can one properly examine the true relative effects of changes in behaviour, such as increased physical activity, or reduced TV watching on energy intake and expenditure (10).

In order to start addressing the sizable gap in existing literature, we investigated the effects of an imposed exercise load on time budgets. This study aimed to investigate how previously inactive adults modify their time budgets when they start a physical activity program. The research question was: How does the adoption of an intensive organised physical activity program change average daily minutes devoted to other use of time domains? This study was conducted within a larger randomised controlled trial aimed at investigating the existence of an activitystat (11).

2 Methods

Ethics approval for this study was gained from the University of South Australia Human Research Ethics Committee. This study used a randomised controlled, multi arm, parallel trial design, with two intervention groups and one control group. Data collection was carried out from January 2011 to February 2012 at the University of South Australia. This analysis was conducted in May 2012. No changes to methods after trial commencement were made and a CONSORT checklist for this paper is included in Appendix 1.

2.1 Participants

Participants for this study were recruited via email and print advertising from a metropolitan university, a tertiary hospital and several government departments. There was no racial or gender bias in the selection of participants. Interested participants were invited to attend a laboratory session to complete informed consent and the Active Australia Survey (12). Participants were required to be insufficiently active (accumulating less than 150 min of moderate to vigorous PA per week on average using the Active Australia Survey), aged between 18-60 years and cleared for exercise under the Sports Medicine Australia pre-exercise screening criteria (13).

2.2 Intervention

Following baseline testing, participants were randomised into one of three groups using a computer generated random allocation sequence by a person external to the study. Participants allocated to the control group were wait-listed for the exercise component of the program once their formal testing was completed and in the meantime, were given no specific instructions other than to continue with their usual routines. Participants in the two intervention groups took part in a 40-day physical activity program (14). Briefly, those randomised to the *Moderate* intervention group were asked to increase their physical activity by 150 min/wk, half of which was to be accumulated in structured, supervised group classes, and half in their own time using modalities of their choice. Those randomised to the *Extensive* intervention group were asked to increase their physical activity by 300 min/wk, half of which was again to be accumulated in supervised classes, and half in their own time.

The supervised sessions consisted of a wide variety of group activities such as circuit classes, sports, boxing, dancing, bushwalking and kayaking. The intensity of these activities increased over the course of the 40 days. For the full protocol including physical activity prescription and activities of both groups, please see Gomersall et al (11). All activity sessions, organised or self-directed, were monitored using heart rate monitors (Polar S610i) and exercise logs. Uncompensated, these sessions would be expected to increase overall daily energy expenditure by approximately 5% (Moderate) and 10% (Extensive).

2.3 Measurements

Control and intervention participants undertook a battery of tests at five time periods during the study: baseline (the week before the program began), mid-program (weeks 3-4), end-program (week 6), and at 3 months and 6 months follow-up. This report will present the baseline, mid-program and end-program results. Measurements of the larger trial included anthropometry (3D whole-body laser scanning, surface anthropometry, height and weight), blood samples, blood pressure, resting metabolic rate, VO_{2max}, doubly labeled water, accelerometry and use of time recalls. The focus of this paper will be the use of time recalls.

The Multimedia Activity Recall for Children and Adults (MARCA), a computerised 24-hour use of time recall tool, was used to capture the time profiles of participants. The MARCA asks participants to recall everything they did in the previous 24 hours from midnight to midnight, using meals as anchor points. Participants can choose from over 500 discrete activities, with the minimum time for an individual activity being five minutes. The MARCA tool was first developed for adolescents (15) and has since been modified and validated for adults (16). Each activity in the MARCA is assigned a MET value based on an expanded version of the Compendium of Physical Activities (17, 18), so that energy expenditure can be estimated. The adult version of the MARCA has test-retest reliabilities in adults of 0.920-0.997 for major activity sets such as sleep, physical activity and screen time, and convergent validity between physical activity level (PAL, estimated average rate of energy expenditure) and accelerometer counts/minute of rho = 0.72 (16). A recent comparison with the gold standard doubly-labeled water (19) showed correlations of rho = 0.70 for total daily energy expenditure.

At each time point, the MARCA was administered by telephone to both intervention and control participants by trained interviewers who were blinded to the group allocation of the participant. Each time, two separate calls were made one week apart, during which participants recalled the two previous days. At each time point (baseline, mid-program and end of program) participants therefore recalled four days of activity, including at least one weekday and one weekend day. For each individual participant, wherever possible, the same days of the week were recalled at all three time points.

2.4 Data treatment

Daily minutes of activity were calculated by summing the number of minutes participants reported being involved in each activity, and averaging them across the four recall days using a 5:2 weighting for weekdays: weekend days. Data was treated in this way as the same days were not always able to be recalled at each time point and in a small number of case (n=2), participants had fewer than four days of recall (minimum of two days, including at least one week day and one weekend day). The 5:2 weighting was applied to adjust for the well recognised differences in week day and weekend physical activity and use of time (20, 21). The 520 activities in the MARCA were combined into "activity sets" and collapsed hierarchically into domains based on similarity and to preserve comparability with previous studies. Eleven mutually exclusive and exhaustive activity "superdomains" were identified: Physical Activity, Computer, Active Transport, Passive Transport, Quiet Time, Self-Care, Socio-cultural, Work/Study, Chores, Sleep, and TV/Videogames. Table 1 contains a description of each superdomain.

Table 1. The 11 superdomain time-use clusters used in this study.

	Superdomain	**Description**	**Examples**
1	Physical Activity	Sport and exercise	Gym Tennis
2	Computer	Using computer except for videogames	Email Internet
3	Active Transport	Walking and cycling	Walking Climbing stairs
4	Passive Transport	Riding or driving motorised transport	Riding in a bus Driving a car
5	Quiet Time	Time spent without interaction	Reading

			Listening to music
6	Self-care	Eating and grooming	Having dinner Showering
7	Socio-cultural	Arts and crafts	Playing the piano Card games
8	Work/Study	Occupational activity and study	Clerical work Homework
9	Chores	Indoor and outdoor household chores	Gardening Food preparation
10	Sleep	All sleep including naps	
11	TV/Videogames	Watching TV and playing videogames on any device	Watching TV X-Box

Activities were also clustered into five mutually exclusive and exhaustive energy expenditure zones: 0-0.9 METs (sleep); 1-1.9 METs (very light PA); 2-2.9 METs (light PA); 3-5.9 METs (moderate PA); and ≥6 METs (vigorous PA). Physical activity level (PAL, in METs) was calculated using the factorial method, that is by multiplying the rate of energy expenditure associated with each activity (in METs), by the number of minutes for which that activity was performed, summing them across the day, and dividing by 1440 (minutes per day). Where time use data were skewed, they were treated as having a gamma or negative binomial distribution. This was the case for all time use variables except Sleep, Self-care, Very Light PA, Light PA, Moderate PA and PAL.

2.5 Statistical analyses

Because this study addresses mechanisms, analyses were performed on a per-protocol basis where only those participants who completed the intervention were included. The primary aim of these analyses was to describe changes in time use during and after an exercise intervention. At each of the three time points, the mean number of minutes spent by participants from each group in each superdomain and energy expenditure zone was calculated. Random effects mixed modeling, with group (Control vs Moderate vs Extensive) as the grouping factor and time use at the three measurement points as the repeated measure was used to compare the mean amount of time each group spent in each superdomain or energy expenditure zone at each time point. Several variables were right skewed (Active Transport, Chores, Computer, Passive Transport, Physical Activity Quiet Time, Socio-Cultural, TV/Videogames and Work/Study). Where this was the case, a generalised mixed model was used and a gamma correction with a log link was applied. A significant group x time interaction effect indicated a significant difference in time use among the groups across the intervention period. Alpha was set at 0.05.

Additionally, paired t-tests are reported to compare the mean amount of time spent in each superdomain or energy expenditure zone from baseline to end intervention, although the main focus of this paper is the group x time interactions according to random effects mixed modeling. The Wilcoxon signed-rank test was used where data were not normally distributed. Alpha was set at 0.05.

A priori power calculations determined that a sample of 26 participants per group (n=78) should be able to detect small to moderate effect sizes (Cohen's d=0.2-0.6) for within groups (time effect) and group x time interactions, at 5% alpha level and 80% power. Due to documented drop out rates of physical activity interventions (22) and the intensive assessment protocol for this study, a minimum total of 43 participants per group was recruited.

3 Results

3.1 Participants

A total of 112 of 129 participants completed the six-week program (Figure 1). Follow up use of time data was available for 111 participants. Characteristics for the finishing participants are shown in Table 2. Most were in full employment in mainly professional or clerical positions, 64% were women, and they came from households which were economically advantaged relative to the general Australian population. On average, participants in the Moderate and Extensive exercise groups complied with 17/ 23 and 28/40 of the prescribed group and individual exercise sessions, respectively, equating to a mean compliance rate of 70±18%.

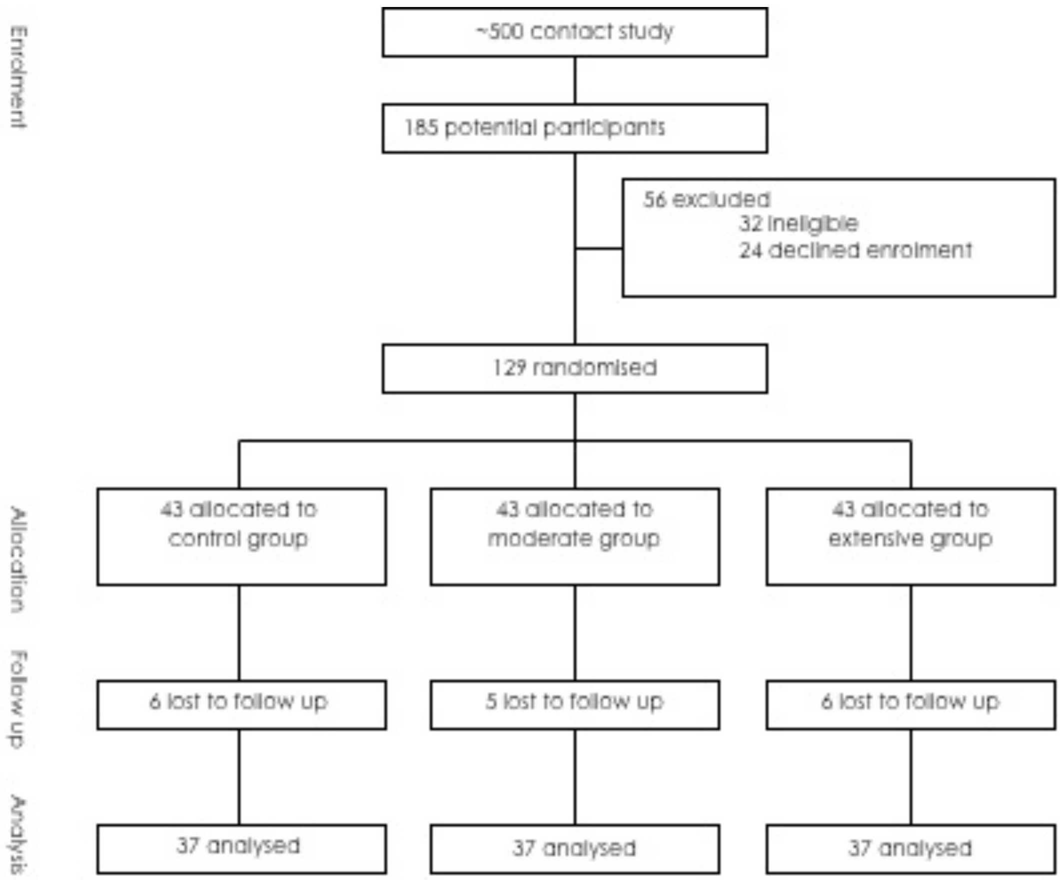

Figure 1. CONSORT flow diagram, showing enrolment, allocation, follow up and analysis.

Table 2. Age, Body Mass Index, household income and gender mix of the intervention and control groups.

[a] Pre-tax income in thousands of Australian dollars per annum. One Australian dollar is approximately equivalent to one US dollar. The mean household income in Australia is about $70,000 p.a..

	Control	Moderate	Extensive
N	37	37	37
Age (years)	42 (10)	41 (12)	45 (10)
Body Mass Index (kg/m^2)	25.8 (6.3)	25.6 (4.9)	26.8 (4.0)
Household income[a]	103 (51)	106 (32)	99 (43)
% Female	59	68	65

3.3 Changes in time spent in different activity superdomains

The average number of minutes per day in each superdomain for each group at each of the three measurement occasions is shown in Table 3. According to random effects mixed modelling analyses, there were no significant differences in use of time between groups at baseline, with the exception of physical activity (where the control group participants accrued four minutes less per day than participants in the Moderate and Extensive exercise groups). However, over the course of the intervention there were significant group x time interactions for several use of time superdomains, namely Physical Activity, Active Transport, Sleep and TV/Videogames. Not surprisingly, the time devoted to Physical Activity and Active Transport was greater in the intervention groups than the control ($p<0.001$) at mid- and end-program and there was less time devoted to Television/Videogames ($p=0.04$). There were no significant differences in time commitments between intervention and control groups in any of the other activity superdomains.

Table 3. Mean (SD) time (min/d) spent in each superdomain by each of the groups at each time point, and P-values for main effects of group and time, and group x time interactions. Significant differences are indicated in **bold**. Values with the same superscript are significantly different on post-hoc analysis.

Super-domain	Period	Control	Moderate	Extensive	P Group	P Time	P Group x Time
Physical Activity	**Baseline**	6 (17)[ab]	10 (20)[a]	10 (22)[b]	**<0.001**	**<0.001**	**<0.001**
	Mid	5 (14)[a]	15 (15)[a]	44 (25)[a]			**<0.001**
	End	2 (5)[a]	28 (32)[a]	52 (42)[a]			**<0.001**
Computer	**Baseline**	203 (131)	185 (112)	181 (106)	0.99	**<0.001**	0.70
	Mid	153 (93)	145 (119)	166 (131)			0.29
	End	123 (88)	145 (109)	140 (95)			0.43
Active Transport	**Baseline**	52 (28)	58 (29)	60 (45)	0.47	0.52	0.67
	Mid	49 (32)[a]	60 (31)	70 (37)[a]			**0.03**
	End	39 (27)[ab]	67 (32)[a]	69 (30)[b]			**<0.001**
Passive Transport	**Baseline**	93 (36)	72 (35)	85 (44)	**<0.001**	0.52	0.08
	Mid	85 (33)	81 (42)	83 (36)			0.93
	End	89 (43)	86 (40)	88 (43)			0.97
Quiet Time	**Baseline**	72 (50)	65 (50)	45 (35)	0.21	**0.03**	0.08
	Mid	59 (50)	48 (42)	48 (38)			0.34
	End	63 (70)	62 (51)	48 (54)			0.34
Self-care	**Baseline**	124 (24)	114 (38)	119 (28)	0.33	0.30	0.48
	Mid	122 (31)	123 (41)	126 (30)			0.86
	End	121 (37)	117 (31)[a]	135 (37)[a]			**0.04**
Socio-cultural	**Baseline**	106 (77)	118 (78)	113 (71)	0.55	0.34	0.73
	Mid	100 (64)	117 (82)	108 (74)			0.65
	End	96 (75)	110 (62)	99 (61)			0.68
Work and Study	**Baseline**	72 (77)	71 (80)	78 (79)	0.64	**0.02**	0.73
	Mid	113 (103)	98 (98)	92 (100)			0.62

	End	103 (104)	95 (106)	89 (78)			0.63
Chores	**Baseline**	133 (65)	115 (75)	138 (97)	0.25	0.54	0.49
	Mid	149 (72)	121 (49)	111 (87)			0.11
	End	155 (75)	118 (65)	131 (90)			0.15
Sleep	**Baseline**	468 (36)	507 (85)	483 (67)	0.06	**0.005**	0.06
	Mid	493 (52)[a]	527 (72)[ab]	492 (60)[b]			**0.05**
	End	508 (51)	514 (86)	492 (62)			0.34
TV/Video games	**Baseline**	112 (59)	125 (68)	129 (89)	0.53	0.08	0.62
	Mid	112 (71)	105 (62)	101 (75)			0.82
	End	144 (52)[ab]	98 (52)[a]	98 (81)[b]			**0.01**

There were several significant time interactions with no group x time interaction effect in the use of time superdomains, indicating changes in time use across all three groups due to factors external to the physical activity intervention (namely in computer use, sleep work and study and quiet time). To isolate the changes due to the physical activity intervention alone, Table 4 and Figure 1 show the shifts in time among superdomains in the Moderate and Extensive groups, relative to changes in the control group. The significant increases in Physical Activity and Active Transport, in the intervention group, relative to control, amounted to 44-62 minutes/day at the end of the intervention. These increases were largely compensated for by a significant reduction in time in Television/Videogames (59-63 min/day). Large, but non-significant shifts in time were also seen in an increase in Computer time (39-40 min/day) and a decrease in Sleep (32-33 min/day) in the intervention groups, compared to the control group.

Table 4. Changes in time spent in the 11 superdomains in the Moderate and Extensive groups relative to the Control group at mid- and end-program.

Superdomain	**Relative to the Control group, the Moderate group spent … more minutes in:**		**Relative to the Control group, the Extensive group spent … more minutes in:**	
	Mid-program	*End-program*	*Mid-program*	*End-program*
Physical Activity	+6	+22	+35	+39
Computer	+10	+40	+35	+39
Active Transport	+5	+22	+14	+23
Passive Transport	+18	+20	+7	+9
Quiet Time	–4	+6	+17	+12
Self-care	+11	+6	+9	+20
Socio-cultural	+4	+2	0	–5
Work and Study	–14	–7	–27	–20
Chores	–10	–19	–43	–29
Sleep	–6	–33	–17	–32
TV/Videogames	–20	–59	–28	–63

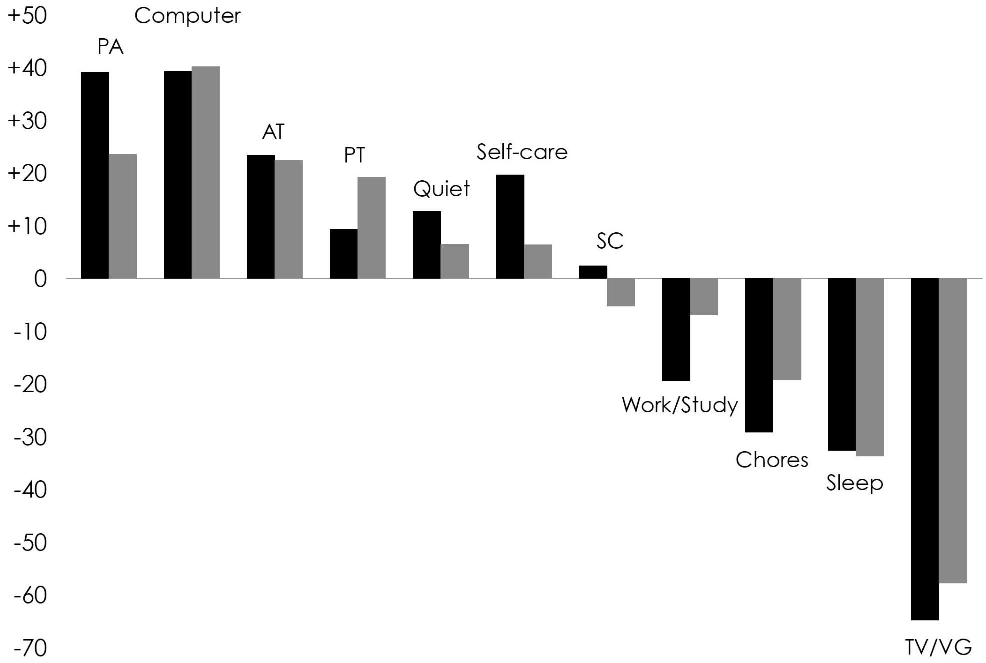

Figure 2. Changes, relative to Controls, from baseline to the end of the intervention in time spent by the Extensive (black bars) and Moderate (grey bars) groups in the 12 superdomains.

AT = Active Transport

PA = Physical Activity

PT = Passive Transport

SC = Socio-cultural

TV/VG = television/videogames

According to paired t-tests, the Control group had significantly decreased the time spent in the Computer (80 min/day) and Active Transport (13 min/day) domains and significantly increased the time spent Sleeping (40 min/day) and watching TV/Videogames (32 min/day) at the end of the program. Both intervention groups demonstrated significant increases in time spent in Physical Activity (18-42 min/day) and significant decreases in time spent watching TV/Videogames (27-31 min/day) by end intervention. In addition, the Moderate group demonstrated a significant increase in Passive Transport (14 min/day) and the Extensive group a decrease in Computer time (41 min/day) and significant increases in Active Transport (9 min/day) and Self-Care (16 min/day).

3.4 Changes in time spent in different energy expenditure zones

The time spent within each energy expenditure zone, by each group at each time period is shown in Table 5. At the end of the intervention, the Moderate and Extensive groups demonstrated significant increases in time spent in the Moderate and Vigorous PA energy expenditure zones and significant increases in PAL.

Table 5. Mean (SD) time (min/d) spent in each energy expenditure zone by each of the groups at each time point, and P-values for main effects of group and time, and group x time interactions. Also shown are data for Physical Activity Level (PAL, in METs). Significant differences are indicated in **bold**. Values with the same superscript are significantly different on post-hoc analysis.

Energy Expenditure Zone	Period	Control	Moderate	Extensive	P Group	P Time	P Group x Time
<1.0 METs (sleep)	**Baseline**	468 (36)	507 (85)	483 (66)	0.06	**0.005**	0.06
	Mid	493 (52)[a]	527 (73)[ab]	492 (59)[b]			**0.05**
	End	508 (51)	514 (86)	492 (63)			0.34
1.0-1.9 METs (Very Light PA)	**Baseline**	662 (75)	657 (85)	641 (108)	0.20	**<0.001**	0.56
	Mid	634 (96)	588 (97)	598 (120)			0.35
	End	629 (112)	598 (109)	568 (109)			0.08

2.0-2.9 METs (Light PA)	**Baseline**	200 (74)	170 (59)	196 (68)	0.43	0.10	0.35
	Mid	201 (64)	201 (64)	203 (80)			0.98
	End	204 (70)	185 (61)	222 (82)			0.11
3.0-5.9 METs (Moderate PA)	**Baseline**	108 (47)	98 (45)	115 (65)	0.36	0.58	0.43
	Mid	104 (53)	113 (74)	109 (39)			0.96
	End	88 (45)[ab]	122 (60)[a]	117 (53)[b]			**0.01**
≥6.0 METs (Vigorous PA)	**Baseline**	3 (8)[ab]	9 (19)[a]	6 (11)[b]	**<0.001**	**<0.001**	**0.009**
	Mid	8 (14)[a]	11 (12)[b]	38 (25)[ab]			**<0.001**
	End	11 (29)[a]	21 (36)[a]	41 (21)[a]			**<0.001**
PAL (METs)	**Baseline**	1.49 (.09)	1.49 (.14)	1.52 (.13)	**<0.001**	**<0.001**	0.70
	Mid	1.51 (0.14)[a]	1.53 (0.12)[b]	1.68 (0.17)[ab]			**<0.001**
	End	1.47 (0.13)[a]	1.58 (0.13)[a]	1.72 (0.16)[a]			**<0.001**

Similar to Table 4, Table 6 shows the shifts in time among energy expenditure zones in the Moderate and Extensive groups, relative to Controls. Large, significant increases were seen in the MPA and VPA energy expenditure zones at the end of the intervention. While there were no significant interactions for a decrease in time spent in the other energy expenditure zones, relative to controls, the Moderate and Extensive groups demonstrated non-significant trends for increasing time spent in the light energy expenditure zone (11-22 min/day) and a decrease in time spent in the Sleep and Very Light PA energy expenditure zones (26-40 min/day) at the end of the intervention.

Table 6. Changes in time spent in the five energy expenditure bands in the Moderate and Extensive groups relative to the Control group at mid- and end-program.

PA = physical activity

Energy Expenditure Zone	**Relative to the Control group, the Moderate group spent … more minutes in:**		**Relative to the Control group, the Extensive group spent … more minutes in:**	
	Mid-program	*End-program*	*Mid-program*	*End-program*
Sleep	–6	–33	–17	–32
Very Light PA	–41	–26	–15	–40
Light PA	+30	+11	+7	+22
Moderate PA	+19	+44	–1	+23
Vigorous PA	–3	+4	+27	+27

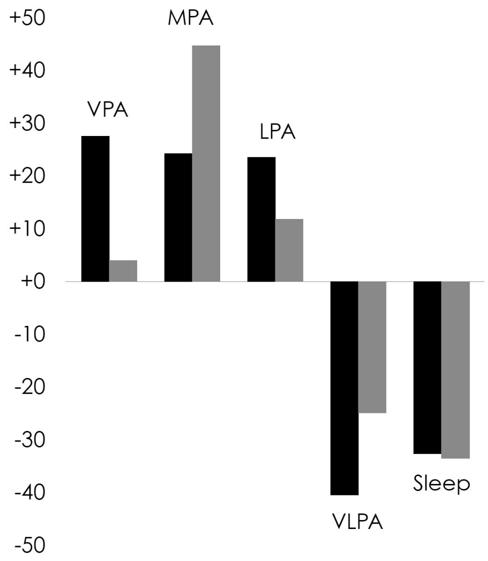

Figure 3. Changes, relative to Controls, from baseline to the end of the intervention in time spent by the Extensive (black bars) and Moderate (grey bars) groups in the different energy expenditure zones.

VLPA = very light physical activity (1-1.9 METs)

LPA = light physical activity (2-2.9 METs)

MPA = moderate physical activity (3-5.9 METs)

VPA = vigorous physical activity (≥6 METs)

According to paired t-tests, the Control group had significantly decreased the time spent in the Very Light PA energy expenditure zone (33 min/day) and significantly increased the time spent in the Sleep zone (41 min/day) at the end of the program. Both intervention groups demonstrated significant increases in time spent in the Vigorous PA zone (12-35 min/day) and significant reductions in time spent in the Very Light PA zone (59-73 min/day) by end intervention. In addition, the Moderate group demonstrated a significant increase in the Moderate PA energy expenditure zone (24 min/day) and the Extensive group a significant increase in the Light PA energy expenditure zone (26 min/day).

4 Discussion

This study examined how adults reorganise their daily use of time when they adopt a new physical activity program. Daily time spent in moderate and vigorous physical activity (in sport and exercise and active transport in particular) significantly increased in the intervention groups, along with overall PAL, and the time was drawn largely from a significant decrease in time spent watching television. The increases in daily physical activity in the exercise intervention groups were commensurate with the imposed exercise load [7 x 21 = 154 min/wk for the Moderate (150 min/wk) group, and 7 x 45 = 273 min/wk for the Extensive (300 min/wk) group].

In the current study, physical activity largely displaced time previously spent watching television in the intervention groups. This reduction in sedentary time may have independent health benefits to participation in the physical activity program alone. Previous research has demonstrated that the amount of time people spend watching television, or more generally, in sedentary behaviour, is linked to increased risk of mortality and morbidity, independent of the time spent in MVPA (23, 24). According to baseline estimates, the participants in this study were spending on average, just over two hours per day watching television and with an additional 150 and 300 min/week of physical activity, television viewing decreased by approximately 59-63 min/day (relative to controls). This is an important reduction in light of the finding that watching two or more hours of television per day has been estimated to increase cardiovascular disease risk by 125% (24). Interestingly, the reduction in television and video game time in this study was at least partially offset by a non-significant increase in computer use relative to controls, perhaps due to participants "taking work home" after leaving work early to get to their exercise sessions. This increase may attenuate the possible benefits of reduced time spent watching television/videogames.

Sedentary time has been reported to be similar in individuals, regardless of time spent in moderate to vigorous physical activity. Using a cross-sectional population and objective monitoring, Craft and colleagues (25) demonstrated that there was no significant difference in sitting time, regardless of whether individuals were meeting, or not meeting physical activity exercise guidelines. In comparison, the present study demonstrates that in an intervention setting, increasing physical activity in previously sedentary adult individuals does in fact reduce the time spent in primarily sedentary behaviours (to the magnitude of 33-60 minutes/day relative to controls, when the primarily sedentary superdomains are summed [Computer, Passive Transport, Quiet Time, Socio-Cultural, Work and Study, Sleep, TV/Videogames]). This is an important finding as it provides support for physical activity interventions to not only increase moderate to vigorous physical activity, but also to reduce sitting time, which is emerging as an important and independent determinant of health.

The current study also demonstrated a non-significant trend for a reduction in sleep duration in the magnitude of 32-33 min/day in the Moderate and Extensive groups, relative to Controls at the end of the intervention. In contrast to the benefits of displacing sedentary time with physical activity, displacing sleep may have negative health impacts. The health effects of a 30 to 40 minute reduction in sleep duration are currently not well understood. Studies which have experimentally manipulated sleep duration have generally used much larger changes in sleep duration, and short-term ill effects of extensive sleep reduction are clearly apparent (26).

While experimental evidence regarding the effects of more modest changes in sleep duration is lacking, epidemiological evidence suggests they may be important. A large meta-analysis of cross-sectional studies including 604,509 adult participants demonstrated a significant increased risk of obesity with sleep duration of 5 hours or less per night (3). Unfortunately, this study did not control for potentially confounding effect of physical activity level (3). However, other studies have suggested that shorter sleep duration is an independent risk factor for hypertension (27, 28) and cardiovascular disease (29), even after controlling for physical activity levels. These results must be interpreted with caution however as they are representative of a non-significant trend relative to change in the Control group. However, while evidence is inconclusive, it appears that the issue of quarantining a minimum duration of sleep may be an important consideration for interventions aiming to increase physical activity.

There is currently no previous literature that charts changes in time use when individuals start a new exercise program. However, the finding that the time required for exercise is drawn from television viewing is consistent with previous use of time literature that has subjectively investigated time use changes using 'virtual' time. In the 1985 American Time Use Survey (30), respondents were asked how they would find the time if they needed an hour for an urgent task. Almost all responded they would reduce television viewing. Another study (31) supports the trend for decreasing sleep that was identified in the current study. When Anderson and Horne (22) asked 10,810 participants what they would do with an extra hour in their day; one in five respondents said they would sleep. It appears that activities such as television watching and sleep constitute time buffers or reservoirs, large pools of time that can be drawn on when there are competing time interests, or increased when time is freed up.

The changes in use of time and estimated physical activity level in this study suggested that the imposed exercise loads were not compensated by reductions in physical activity or energy expenditure in other domains, disconfirming the activitystat hypothesis. However, it is important to note that the opportunity for compensation may be affected by parameters such as the strength of the exercise stimulus, the initial levels of activity in the population, and the time constraints the participants are under (32). In this study, a reasonably 'powerful' exercise stimulus was applied: the intervention was highly structured and it was supervised. Participants were initially inactive, which may have reduced the scope for compensation by drawing on existing levels of physical activity. The participants were also, for the most part, employed in occupations which allowed some flexibility, for example, by catching up with work at home. Indeed the increase in computer use coupled with reductions in work and study time suggest that participants were leaving work early to exercise, and may have been using the internet from home to complete their work. An analysis of shifts in the time distribution of physical activity, computer use and work and study is consistent with this hypothesis.

Few experimental studies make specific references to an activitystat, however there are many that investigate the concept of compensation, although none of these studies has included a measure of use of time. Church et al. (2009) (33) and Hollowell et al. (2009) (34) conducted randomised controlled trials with physical activity interventions of differing loads in sedentary adults. Similar to this study, both of these studies failed to detect compensation in activity outside of the program in any of the groups, as measured by pedometry and accelerometry respectively. This is despite both interventions being considerably longer than the six week intervention in this study, with Church et al. (2009) (35) employing a six month intervention and Hollowell et al. (2009) (34) an eight month intervention.

From baseline to the end of the intervention, the Control group demonstrated a highly variable pattern of time use, with significant changes in time spent on the Computer, Watching TV/Videogames, Sleep and Active Transport to the magnitude of 13-80 min/day at the end of the intervention. This variability is not a surprising finding, time use patterns are widely recognised to be highly variable and are strongly influenced by external factors such as season, work and study constraints, holidays, family commitments and health and illness (36, 37). This finding, in turn, reiterates the importance of including a Control group in intervention studies. The randomised controlled trial design and reporting changes in use of time relative to the Control group are therefore key strengths of the present study and are an important contribution when trying to understand how time use changes when commencing a new exercise program.

Other key strengths of the current study are that it is the first to comprehensively chart changes in use of time across an exercise intervention; it used a validated, reliable, high-resolution 24 hour recall instrument which allowed a wide range of activity domains to be explored; and use of time was assessed before, and throughout the exercise program. Nonetheless, the study had a number of limitations. It used a sample of convenience, and the study sample was predominantly female, well-educated and generally in full employment, thus the results cannot necessarily be generalised to other groups with different time commitments and constraints. At each time point, four days of recall were collected which were kept consistent between measurement occasions wherever possible. For participants in the Extensive condition, participation was required everyday of the six-week program and therefore would have been captured by the sampling protocol. Participants in the Moderate group, however, were scheduled to participate in scheduled activity on seven days per fortnight. While it is possible that the sampling time frame would not have captured some days of participation, according to the scheduled physical activity program, the protocol would have captured at least two exercise days. While the use of time instrument used minimised bias by requiring individuals to account for all 24 h in the day, we cannot discount social desirability and recall bias.

Finally, this study highlights some practical considerations for future physical activity intervention research and prescription of physical activity in general. Findings suggested “collateral time costs” are associated with exercise, for example, the increase in time spent on self-care activities and passive transport increases. These collateral time costs are often overlooked, but are logical, given that when we exercise, we often need to find time to change in and out of exercise clothes, shower and get to and from an exercise venue. In addition, findings suggest that the activities that are displaced by the exercise program are important as they may either potentiate or, or alternatively, mitigate the benefits of additional physical activity. Given the contributing relationships between these time use activities and health outcomes, it appears that educating participants about the exchanges in time use that occur when taking up a new exercise program may be useful, in order to maximise the net health gains associated with physical activity adoption. Further research could aim to determine whether such education affects the use of time buffers identified in the current study. Finally, the current study highlights that when people take up a new exercise program, there are sizeable changes in other time use behaviours. As such, it appears that physical activity intervention studies should measure changes in use of time in order to fully evaluate their effects.

In conclusion, this study used a randomised controlled trial to investigate changes in time use in previously sedentary adults when commencing two different volume exercise programs. Including a time use measure is a novel approach in the physical activity literature and allowed us to comprehensively chart where the time comes from to accommodate a new exercise program. The time for increased physical activity was largely drawn from time spent watching television and non-significant trends for a reduction in time spent sleeping and an increase in computer time in the intervention groups compared to Controls was identified. While it is encouraging to see a trade-off in sedentary time to accommodate physical activity, it is important to note the potential effect of trading behaviours such as sleep which have negative health outcomes. These results show that how time is exchanged may influence the overall net health benefits of increased physical activity and have implications for the prescription of new exercise programs.

What are the new findings?

- This study is the first study to comprehensively map changes in time use when commencing a new exercise program.
- Intervention groups spent significantly more time in overall moderate to vigorous physical activity domains of time use (including Active transport and Physical Activity)
- Time was largely drawn from Watching Television/Videogames domain
- Large, but non significant shifts in time were also seen in an increase in Computer time and a decrease in Sleep in the intervention groups

How might it impact clinical practice:

- Shifts in time away from sedentary behaviours, such as watching television, is a promising finding for additional health benefits associated with increased physical activity
- Conversely, decreased sleep and increased time on the computer may have a negative influence on the overall health benefits of additional physical activity

- This study highlights the importance of monitoring the collateral time costs of commencing a physical activity program as these ripple effects may have both positive and negative health implications

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