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Changes in 24-h Movement Behaviors During Relationship and Parenthood Transitions: A Compositional Data Analysis

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ABSTRACT

There is scarcity of studies using device-based measures to examine how relationship and parenthood transitions modify 24-h movement behaviors. This study examined how the composition of 24-h movement behaviors changes during these life transitions. Young adults ($n = 170$, mean age 25.6 years, SD 0.6) from the Special Turku Coronary Risk Factor Intervention Project (STRIP) wore wrist-worn accelerometers for 1 week and completed questionnaire at ages 26 and 31 years. Participants were categorized by relationship status into single (16%), those transitioning from single to partnered (31%), partnered (47%), and separated (7%), and by parenthood status into non-parents (73%), new parents (19%), and parents (8%). Changes in daily movement behaviors, including sleep, sedentary behavior (SED), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA), were examined using compositional linear mixed models. In general, LPA and MVPA decreased relative to sleep and SED ($p = 0.007$). Differences emerged between LPA and MVPA in relationship and parenthood groups (p for group × time interaction 0.008 and 0.001). Those transitioning to partnership decreased MVPA by 17 min/day, while partnered and separated individuals showed no notable MVPA change but decreased LPA by 14 and 43 min/day. Single individuals and non-parents decreased LPA and MVPA in similar proportions. New parents decreased MVPA by 20 min/day, while parents increased it by 19 min/day. Becoming first-time parent and starting relationship was associated with decline of MVPA. Our results suggest the importance of considering these life transitions and providing guidance for maintaining physical activity despite changes in life situations.

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1 | Introduction

Physical activity is one of the key modifiable behaviors in promoting health and preventing chronic diseases [1], along with sufficient sleep [2] and limiting excessive sedentary behavior (SED) [3]. Therefore, it is important to examine factors that may modify these behaviors. Life transitions such as changes in relationship status and becoming a parent are common across young adulthood and may modify daily routines, time use and psychological well-being, and consequently also change physical activity, SED, and sleep [4, 5]. Previous prospective longitudinal studies have mainly reported decreasing self-reported leisure-time physical activity when moving in together or getting married [6–10]. Conflicting findings have been reported for breaking up a relationship or divorce, as both positive [10] and negative [7], as well as no associations [6, 11] have been found. No changes in self-reported sitting time have been observed across relationship transitions in a prospective follow-up study [12]. Previous prospective longitudinal studies have also shown that becoming a parent decreases self-reported leisure-time physical activity [6–8, 12, 13], self-reported sitting time [12], and sleep duration [14]. However, survey studies in general are affected by recall, information, and social desirability bias [15], and they do not provide information on how all daily movement (e.g., incidental physical activity, occupational physical activity, etc.) and non-movement activities change across the aforementioned life transitions in early adulthood.

Device-based studies offer more accurate information compared with surveys on how total daily physical activity, sedentary time, and sleep change across life transitions. However, to the best of our knowledge, there is only one previous prospective pedometer-based study on changes in daily step count across relationship transition [16] and one previous prospective accelerometer-based study on changes in physical activity and SED across parenthood transition [17]. In the pedometer-based study among 30- to 45-year-old Finnish adults, women who started a relationship decreased their daily step count compared to women who remained in a relationship across the 4-year follow-up [16]. No significant differences were observed between those who were single or became divorced across the follow-up when compared to those who remained in a relationship, nor among men. The prospective 1-year study among 30-year-old Canadian adults with waist-worn accelerometer showed that moderate-to-vigorous physical activity (MVPA) and also sedentary time decreased, while light physical activity (LPA) increased after having a first child, but only among women [17].

In addition to scarcity of device-based studies on changes in physical activity, sedentary time and sleep across relationship and parenthood transitions, it is not known how all movement behaviors during the 24-h day, that is, sleep, sedentary time, LPA, and MVPA, often referred as "24-h movement behaviors" change in relation to each other across these life transitions. It has been acknowledged that increasing one behavior, for instance physical activity, inevitably leads to a compensatory effect of decreasing at least one of the remaining behaviors, because 24-h movement behaviors are bound to a 24-h day [18, 19]. Consequently, there has been a shift from examining movement behaviors in isolation into a 24-h time use perspective [19]. The codependency between 24-h movement behaviors can be taken into account using statistical methods such as compositional data analysis (CoDA) that treats movement behaviors as relative and codependent in nature [18–20].

To fill these gaps in previous research, we utilized a CoDA methodology to examine how device-measured 24-h movement behaviors change in relation to each other across relationship and parenthood transitions over 5 years. Identifying critical time points for changing 24-h movement behaviors could aid planning of successful and well-timed interventions. Based on previous literature, we hypothesize that starting a relationship is associated with decreasing physical activity [6–10, 16], while the opposite may be seen for those whose relationship ends [7]. We further hypothesize that becoming a parent is associated with decreased MVPA, SED, and sleep [6–8, 12–14, 17] but increased LPA [17].

2 | Methods

2.1 | Study Population

The Special Turku Coronary Risk Factor Intervention Project (STRIP) study is a prospective, randomized controlled trial aiming to prevent atherosclerosis beginning in infancy [21]. A detailed description of the study design has been reported elsewhere [21, 22]. In brief, families of 5-month-old infants, born between July 1989 and December 1991, were recruited at well-baby clinics in Turku, Finland by the clinic nurses. The intervention group received dietary intervention between the ages of 7 months and 20, while control group received the basic health education given at Finnish well-baby clinics and school health care.

The first post-intervention follow-up was conducted between April 2015 and January 2018 when participants were 26 years old, and 1072 study participants were invited to participate to clinical study visit [23, 24]. In total, 546 attended the study visit, and of them, 402 (74%) participated in accelerometer measurement. Those who used accelerometer successfully at the age of 26 years ($n = 396$) were invited approximately 5 years later by email or phone to a new follow-up including accelerometer measurement and a web questionnaire. Of the invited, 223 (56%) participated and measurements were conducted between May 2021 and February 2022 when the participants were approximately 31 years old.

Formation of the study sample is illustrated in Appendix S1. To this study, we included those participants who had sufficient amount of accelerometer data at both time points, that is, age 26 and 31 years ($n = 170$) based on the commonly used criteria, that is, at least four valid measurement days of at least 10 h of waking wear time per day [25]. Moreover, because the focus was on the relationship and parenthood transitions, we only included those participants who had provided information on marital status, number of children, and covariates at both time points, leaving 157 participants to the study sample for relationship transitions and 154 participants to the study sample for parenthood transitions.

2.2 | Assessment of Relationship and Parenthood Transitions

Relationship and parenthood status was captured by self-administered questionnaires at both time points. Participants were categorized into four relationship groups: Single, that is, those who were single, divorced, or widowed at both time points, Single to partnered, that is, those who were single, divorced, or widowed at baseline and in a relationship (marriage/cohabitation) at the follow-up time point; Partnered, that is, those who were married or cohabiting at both time points; and Separated, that is, those who were in a relationship (marriage/cohabitation) at baseline and either single, divorced, or widowed at the follow-up time point.

Based on participants' self-reported number of children, participants were categorized into three parenthood groups: Non-parents, that is, those who had no children at both time points, New parents, that is, those who had no children at baseline and had their first child/children during the follow-up and Parents, that is, those who already had one or more children at baseline ($n = 7$, 58% in this group had more children during the follow-up).

2.3 | Assessment of 24-h Movement Behaviors

Triaxial ActiGraph wActiSleep-BT accelerometer (ActiGraph, Pensacola, Florida, US) was used to estimate the 24-h movement behaviors, that is sleep, SED, LPA, and MVPA. The accelerometer was initialized to record at 80 Hz. At baseline, an assisting study person guided participants on the use of accelerometers during the study visit. At the follow-up time point, accelerometers with instructions were mailed to participants. At both time points, participants were instructed to wear the accelerometer on their non-dominant wrist for the following 8 days at all times, 24 h/day, including during water-based activities such as swimming, but to remove it for sauna. In an accompanying log, the participants were asked to record date, waking time, and bedtime on each measurement day. After the measurement period, the participants returned the accelerometer and the log by mail. Data from the accelerometers were downloaded in the ActiLife software, version 6.13 (ActiGraph, Pensacola, Florida, US). At the baseline measurement, accelerometer data were collected between April 2015 and March 2018 and at the follow-up measurement between May 2021 and February 2022. The duration of follow-up was on average 4.9 years (range 3.9–6.3 years).

The accelerometer data were processed using previously reported methods [26]. Shortly, the R-package GGIR version 1.7–1 [27] was used to estimate 24-h movement behaviors, after detecting and excluding non-wear time. Sleep time was detected based on the combination of the daily logs and algorithm of the GGIR package [28], so that sleep was defined as periods of time within the bedtime and waking times reported in the daily logs during which there was no change larger than 5° in the arm angle over at least 5 min. Wake time SED, LPA, and MVPA were defined using the threshold values of < 30 mg, at least 30 mg but less than 100.6 mg, and ≥ 100.6 mg, respectively [29, 30].

The measurement day was determined from each measurement day's bedtime to the next measurement day's bedtime. The analyses were restricted to valid measurement days with at least 10 h of waking wear time. No specific restrictions were made regarding night duration. The average duration of a valid measurement day was 24.1 h (range 22.4–26.2, interquartile range (IQR) 23.9–24.2) at baseline and 23.8 h (range 22.6–24.7, IQR 23.6–24.0) at follow-up, indicating very good compliance for the 24-h measurement. Weekly compositional means of time spent in each behavior were calculated and scaled to be proportional to 24-h day.

2.4 | Covariates

Sex and level of education at baseline (1. basic, i.e., at least upper secondary education, or 2. advanced, i.e., education obtained from university or university of applied sciences, whether ongoing or completed) were assessed with a self-administered questionnaire. Baseline weight and length were measured by a study nurse for calculation of baseline body mass index (kg/m^2).

2.5 | Statistical Analysis

The baseline characteristics of the study population were presented as mean values and SDs for the continuous variables and as frequencies and percentages for the categorical variables. As an attrition analysis, we studied whether the sociodemographic and 24-h movement behaviors at baseline (at 26-year measurement) differed between the current study population ($n = 155/152$) and those who were invited to 31-year accelerometer measurement but did not participate ($n = 173$). For categorical variables, the χ^2 test and for continuous variables, the Student's t-test was used.

2.6 | Compositional Data Analysis

The proportion of time spent in each behavior was treated as compositional data. The analyses were conducted using the packages compositions [31], robCompositions [32] and nlme [33] in R version 4.3.1 [34]. The compositional means were calculated as the component-wise geometric means of the data, and rescaled to sum up to 1440 min.

An isometric log ratio (ilr) transformation was used to map the compositional data into real-valued coordinates, which reduces the dimensionality of the data and allows standard statistical methods to be used [20]. The specific type of ilr-coordinates used in this study were balance coordinates. The balance coordinates were formed by assigning compositional parts into opposing groups, with each coordinate pertaining to a positive or negative group. These groups were then used to calculate the coordinates in such a way that each coordinate represents the ratio of the sizes of its groups, in other words how much larger the combined proportional size of the parts in one group is compared to the parts in the other group [26, 35]. The groups of compositional parts for each coordinate were chosen using sequential binary partitioning. First, the active behaviors, LPA, and MVPA were selected as positive, and the passive behaviors, sleep, and SED were selected as negative (balance coordinate 1). These subcompositions correspond to the first coordinate of the transformation, with positive values of the coordinate indicating that the proportion of the positive group is higher and vice versa. For the second coordinate, the parts of the previous positive subcomposition, that is, active behaviors, were divided with LPA selected as positive and MVPA selected as negative (balance coordinate 2). Thus, positive values of the second coordinate corresponded to the proportion of LPA being higher in the ratio of LPA versus MVPA. Finally, for the third coordinate, the negative subcomposition, that is, the passive behaviors, was divided with positive values corresponding to the dominance of SED in the ratio of SED versus sleep (balance coordinate 3). Compared to the first balance coordinate, the second coordinate contains information only about the relationship between LPA and MVPA and not their relationship to the other two passive components and, similarly, the third coordinate contains information only on the relationship between SED and sleep.

After the coordinate transformation was applied to the compositional data, separate linear mixed models were fitted for each of the three coordinates to study the changes in the 24-h movement behaviors across the follow-up among all study participants and by relationship and parenthood groups. In Model 1, the main effect of time on the first balance coordinate (active vs. passive behaviors) was examined, adjusting for sex, education and BMI. In Model 2, the modifying effect of relationship group/parenthood group was examined by adding the interaction term relationship group × time/parenthood group × time to the Model 1. Both models were repeated for the balance coordinate 2 (LPA vs. MVPA) and balance coordinate 3 (SED vs. sleep). In the models, each participant was given a random intercept and a random slope of time.

2.7 | Time Flow Analysis

As a complementary analysis, time flow analysis, described in detail previously [36], was used to illustrate the amount of time flowing between the 24-h movement behaviors from baseline to follow-up. Time flows were calculated for each individual by comparing each 5-s interval at baseline with the available corresponding 5-s interval at follow-up, matched by the day of the week. A change in any movement behavior during the 5-s interval was added to the time flow. Daily time flows were calculated for each individual and averaged across all participants by the relationship and parenthood groups. Finally, daily time flows were averaged across all weekdays and weekend days to express average weekly time flow for the relationship and parenthood groups. Results of time flows between movement behaviors (inflows and outflows) were graphically presented in chord diagrams using the circlize package in R [37]. Net time flows were further calculated by subtracting the time flows out of a certain movement behavior to another given movement behavior (for instance, from sleep to SED) from the corresponding time flows in (i.e., from SED to sleep).

3 | Results

3.1 | Participant Characteristics

At baseline, the mean age of the participants was 25.6 years (SD 0.6), and the majority of them were women (62%) and had high education (69%) (Table 1). The highest proportion of the study participants were in a relationship (47%), while 31% started a relationship, 16% were single, and 7% separated during the follow-up. The proportion of women was lowest among those who were single at both time points (48%) and highest in the group who separated (91%). Moreover, those in a relationship or starting a relationship tended to be leaner compared to single individuals and those who separated. Of those transitioning from single to partnered and those separated, 17% and 9% also became parents, respectively.

Most of the study participants were non-parents (73%), while 19% became new parents and 8% were already parents at baseline. Non-parents tended to have higher BMI compared to new parents and parents, but no other differences in baseline characteristics were observed between the parenthood groups. Of the new parents, 28% also transitioned from single to partnered and 3% separated during the follow-up.

In the attrition analyses, there were no differences in terms of baseline marital or family status, education, or BMI between the current study populations and those who participated in 26-yr accelerometer measurement but not in 31-yr accelerometer measurement (Appendix S2). However, there tended to be more women and those with higher proportions of LPA and MVPA and less SED among the current study populations.

3.2 | Changes in 24-h Movement Behaviors

Among the whole study population ($n = 170$), the baseline daily compositional mean of 24-h movement behaviors included 8.1 h of sleep, 11.0 h of SED, 3.3 h of LPA, and 91 min of MVPA. On average, sleep increased by 4 min, SED increased by 14 min, LPA decreased by 10 min, and MVPA decreased by 9 min per day during the 5-year follow-up (Table 2). Consequently, the composition of 24-h movement behaviors changed so that active behaviors (LPA, MVPA) decreased in relation to the passive behaviors (sleep, SED) ($p = 0.007$). There was no change in the relation between LPA and MVPA ($p = 0.14$), or between SED and sleep ($p = 0.49$) during the follow-up.

3.2.1 | Relationship Transitions

Compositional means by relationship groups at baseline and follow-up measurements are presented in Table 2. At baseline, there were no marked differences in sleep duration between the groups (7.9–8.2 h). Those who were single at baseline, that is, single individuals and those who transitioned from single to partnered, had more SED (11.3–11.7 h) and less LPA (2.8–2.9 h) compared to those who were in a relationship at baseline, that is, those partnered at both time points and those who separated (SED 10.6–10.7 h, LPA 3.8–4.1 h). The amount of MVPA at baseline varied

TABLE 1 | Baseline participant characteristics by relationship and parenthood groups.

	All, n = 168	Relationship groups: Single	Single to partnered	Partnered	Separated	Parenthood groups: Non-parents	New parents	Parents
Age, mean (SD)	25.6 (0.6)	25.6 (0.6)	25.6 (0.6)	25.6 (0.5)	25.7 (0.5)	25.6 (0.5)	25.5 (0.6)	25.7 (0.5)
Women, n (%)	106 (62)	12 (48)	32 (67)	47 (64)	10 (91)	74 (65)	17 (59)	8 (67)
Education, n (%)								
Basic	52 (31)	7 (28)	12 (25)	24 (33)	6 (55)	36 (32)	9 (31)	3 (25)
Advanced	114 (69)	18 (72)	36 (75)	49 (67)	5 (45)	77 (68)	20 (69)	9 (75)
Relationship group, n (%)								
Single	25 (16%)	—	—	—	—	24 (21)	0 (0)	0 (0)
Single to partnered	48 (31%)	—	—	—	—	37 (33)	8 (28)	1 (8)
Partnered	73 (47%)	—	—	—	—	42 (38)	20 (69)	10 (83)
Separated	11 (7%)	—	—	—	—	9 (8)	1 (3)	1 (8)
Parenthood group, n (%)								
Non-parents	113 (73%)	24 (100)	37 (80)	42 (58)	9 (82)	—	—	—
New parents	29 (19%)	0 (0)	8 (17)	20 (28)	1 (9)	—	—	—
Parents	12 (8%)	0 (0)	1 (2)	10 (14)	1 (9)	—	—	—
Body mass index, mean (SD), kg/m^2	24.2 (3.9)	25.0 (5.4)	23.6 (3.2)	24.1 (3.5)	25.8 (4.8)	24.3 (4.1)	23.3 (2.8)	23.1 (2.9)
Number of valid measurement days, range	6.7 (5–7)	6.8 (5–7)	6.6 (5–7)	6.8 (5–7)	6.5 (6–7)	6.7 (5–7)	6.6 (6–7)	6.6 (6–7)

between 85 and 98 min per day, those being single or partnered having the lowest amounts of MVPA and those transitioning from single to partnered having the highest amount.

During the 5-year follow-up, all groups tended to increase their sleep and/or SED, while some differences were observed in changes of LPA and MVPA between the groups. The change in the ratio of LPA versus MVPA (balance coordinate 2) depended on relationship group (p for group × time interaction 0.008) (Table 3). Borderline significant difference in the change was observed between single individuals and those who partnered during the follow-up (p = 0.07). Among single individuals, both LPA and MVPA decreased in similar proportions (Table 2); thus, the relation of LPA and MVPA did not change notably. In contrast, among those who partnered during the follow-up, LPA increased relative to MVPA, because MVPA decreased markedly but LPA did not change notably. Finally, among those partnered at both time points and those separated, LPA decreased relative to MVPA, more among those who separated. Changes in active versus passive behaviors (balance coordinate 1) and SED versus sleep (balance coordinate 3) did not differ between the relationship transition groups (p for group × time interactions 0.71 and 0.89, respectively).

Time flow between 24-h movement behaviors in different relationship groups is illustrated in Figure 1. Among single and partnered individuals, time outflow from LPA and MVPA was mostly explained by time flow to SED, and much less time flowed back from SED to LPA and MVPA, leading to the net time flows from LPA and MVPA to SED. Among those who transitioned from single to partnered, the main contributor of decreasing MVPA was the net time flow from MVPA to SED. For instance, 52 min/day flowed from SED to MVPA, but 65 min/day flowed back from MVPA to SED, leading to a net time flow from MVPA to SED by 13 min/day. Among those who separated, the main contributor of decreased LPA was the net time flow from LPA to SED.

3.2.2 | Parenthood Transitions

Daily compositional means by parenthood groups at baseline and follow-up measurements are presented in Table 2. At baseline, all groups had relatively similar sleep duration (8.1–8.3 h per night). Those who had no children at baseline, that is, non-parents and new parents, had more MVPA compared to parents (90–94 min vs. 66 min per day), but less LPA (3.2–3.5 h vs. 3.9 h per day).

The change in the ratio of LPA versus MVPA (balance coordinate 2) depended on parenthood group (p for group × time interaction 0.001) (Table 3). Changes differed significantly between non-parents and new parents (p = 0.002). Among non-parents, the relation of LPA and MVPA did not change notably, because

TABLE 2 | The daily mean hours/min for each 24-h movement behavior by relationship and parenthood groups. The means are scaled to 1440 min (24 h).

		Relationship groups				Parenthood groups		
	All	Single	Single to partnered	Partnered	Separated	Non-parents	New parents	Parents
Baseline, h/min (%)								
Sleep	8.1 (34)	8.1 (34)	8.2 (34)	8.1 (34)	7.9 (33)	8.1 (34)	8.3 (34)	8.3 (34)
SED	11.0 (46)	11.7 (49)	11.3 (47)	10.7 (45)	10.6 (44)	11.1 (46)	10.7 (45)	10.8 (45)
LPA	3.3 (14)	2.8 (12)	2.9 (12)	3.8 (16)	4.1 (17)	3.2 (13)	3.5 (15)	3.9 (16)
MVPA	91 (6)	87 (6)	99 (7)	86 (6)	91 (6)	94 (7)	90 (6)	66 (5)
Follow-up, h/min (%)								
Sleep	8.2 (34)	8.3 (34)	8.3 (35)	8.1 (34)	8.1 (34)	8.2 (34)	8.3 (34)	7.9 (33)
SED	11.3 (47)	12.1 (50)	11.4 (47)	11.0 (46)	10.9 (46)	11.5 (48)	10.9 (45)	10.8 (45)
LPA	3.2 (13)	2.4 (10)	3.0 (12)	3.5 (15)	3.4 (14)	2.9 (12)	3.7 (15)	3.9 (16)
MVPA	82 (6)	74 (5)	82 (6)	82 (6)	95 (7)	85 (6)	70 (5)	85 (6)
Change, min (%)								
Sleep	+4 (+1)	+14 (+3)	+7 (+1)	+1 (+0.1)	+16 (+3)	+8 (+2)	+1 (+0.1)	−21 (−4)
SED	+14 (+2)	+23 (+3)	+6 (+1)	+18 (+3)	+23 (+4)	+19 (+3)	+8 (+1)	+2 (+0.3)
LPA	−10 (−5)	−24 (−14)	+5 (+3)	−14 (−6)	−43 (−17)	−18 (−9)	+11 (+5)	−0.3 (−0.1)
MVPA	−9 (−10)	−13 (−15)	−17 (−17)	−4 (−4)	+4 (+4)	−9 (−10)	−20 (−22)	+19 (+29)

Abbreviations: LPA = light physical activity, MVPA = moderate-to-vigorous physical activity, SED = sedentary time.

both decreased in relatively similar proportions (Table 2). In contrast, among new parents, MVPA decreased relative to LPA, whereas among parents MVPA increased markedly relative to LPA (Table 2). Changes in active versus passive behaviors (balance coordinate 1) and SED versus sleep (balance coordinate 3) did not differ between the parenthood groups (p for group × time interactions 0.11 and 0.87, respectively).

Among non-parents, decreased LPA and MVPA were largely explained by the net time flow from LPA and MVPA to SED (Figure 2). Among new parents, the main contributor to markedly decreased MVPA level was the net time flow from MVPA to SED. For instance, 44 min/day flowed from SED to MVPA, but 59 min/day flowed back from MVPA to SED, leading to a net time flow from MVPA to SED by 15 min/day. Among parents, time inflows to MVPA were larger than outflows from MVPA, so increased MVPA was explained by the net time flows from all other behaviors to MVPA. Moreover, parents' decreased sleep was mostly explained by higher time outflow from sleep to LPA compared to time inflow from LPA to sleep.

4 | Discussion

This prospective longitudinal study examined changes in 24-h movement behaviors across common life transitions in young adulthood, namely relationship and parenthood transitions. We observed a general decline in both LPA and MVPA in relation to sleep and SED across the 5-year follow-up among young adults. However, our findings suggest that life transitions in early adulthood bring some fluctuation in the levels of LPA and MVPA, which is reflected in the levels of SED and sleep. Especially becoming a first-time parent and starting a relationship seemed to fortify replacing MVPA with SED.

Our study offers new insights into how device-measured 24-h movement behaviors change across relationship transitions among young adults. We observed that while those whose relationship status did not change followed the general trend of decreasing both MVPA and LPA relative to sleep and SED, those who started a relationship decreased their MVPA, but not LPA, and those who separated showed a marked decrease in LPA but a slight increase in MVPA. Our results generally support our literature-generated hypothesis and add to the previous findings among young women from the Australian Longitudinal Study on Women's Health (ALSWH) [6, 7, 9], young adults from the United States [8], and Finnish adult populations [10, 16], which suggest that starting a relationship is associated with decreased self-reported leisure-time physical activity and daily total steps. To date, the underlying reasons for these changes have remained obscure; thus, more insight is needed to understand why MVPA drops after starting a relationship. It has been speculated that as a single, an individual may have more motivation to exercise because physical fitness is seen as a desirable trait when choosing a partner and the motivation to exercise may attenuate after

TABLE 3 | Estimated fixed effects of changes in the compositional parts and their 95% confidence intervals by relationship and parenthood groups from the linear mixed models.

	Relationship groups				Parenthood groups			
	β	95% CI		*p*	*β*	95% CI		*p*
Balance coordinate 1: Active versus passive behaviors								
Model 1								
Time	**−0.10**	**−0.16**	**−0.03**	**0.005**	**−0.10**	**−0.17**	**−0.03**	**0.005**
Group	**0.09**	**0.02**	**0.16**	**0.02**	0.02	−0.08	0.11	0.72
Model 2								
Time × group				0.71				0.11
Balance coordinate 2: LPA versus MVPA								
Model 1								
Time	0.03	−0.02	0.08	0.29	0.03	−0.03	0.08	0.31
Group	**0.09**	**0.05**	**0.14**	**0.0002**	**0.17**	**0.11**	**0.24**	**< 0.0001**
Model 2								
Time × group				**0.008**				**0.001**
Balance coordinate 3: SED versus sleep								
Model 1								
Time	0.01	−0.02	0.03	0.51	0.01	−0.01	0.03	0.42
Group	−0.01	−0.04	0.01	0.33	−0.03	−0.06	0.01	0.09
Model 2								
Time × group				0.89				0.87

Note: Model 1: adjusted for sex, education, and BMI. Model 2: Model 1 + group × time interaction term. Balance coordinate 1 is for active versus passive movement behaviors, balance coordinate 2 for LPA (light physical activity) versus MVPA (moderate-to-vigorous physical activity), and balance coordinate 3 for SED (sedentary behavior) versus sleep. Bolded values indicate $p < 0.05$.

starting a relationship [10]. We further speculate that starting a relationship might change daily physical activity routines closer to the partner's routines, which may influence physical activity behavior in different ways depending on the partner (e.g., physically active vs. inactive partner). In our study, the main contributor to decreasing MVPA among those starting a relationship was the replacement of MVPA with SED. Thus, activities with a new partner likely included more time use in sedentary activities, such as watching TV and sedentary social activities with friends and family (e.g., evening get-togethers), which leave less time for leisure-time physical activity accruing MVPA. However, relationship-related activities that include going out from home likely accrue LPA, which may explain why those starting a relationship sustained their LPA levels while single individuals did not. The end of a relationship may decrease time use in these activities and could then explain the observed decrease in LPA, but on the other hand, it may leave more time for leisure-time physical activity.

Our findings also indicate that becoming a parent was associated with a marked decrease in MVPA, mostly explained by the replacement of MVPA with SED, which outperformed the decrease in MVPA observed among non-parents. This supports our hypothesis and is line with previous literature among young adults from the United States [7, 13], Australia [6, 7, 12] and Canada [17] showing decreases in self-reported leisure-time physical activity and accelerometer-measured daily MVPA after having a child. There are several possible explanations for these findings. Parents often report lack of time and childcare obligations as common barriers for engagement in physical activity [38]. Thus, increased time use in childcare and household chores likely leave less time for leisure-time physical activity, that is an important source of MVPA. Childcare and household chores likely accrue some LPA, which may explain why levels of LPA did not drop after becoming a parent. A possible explanation for the replacement of MVPA with SED may be the previously observed decrease in sleep quality after becoming a parent [14], which may increase the need for daytime resting and, for example, napping. In our study, sleep periods were detected within the bedtime and waking times reported in the daily logs [28], and therefore daytime napping was likely captured as SED. Parents' poor sleep quality might also affect physical activity, as parents often perceive fatigue as a barrier for physical activity [38].

This study concerns relationship and parenthood transitions that occurred within the 5-year follow-up time window; thus, these life transitions could have taken place at any time during that time window. Unfortunately, we did not have information on the exact timing of the life events and we were not able take into account the time until follow-up measurement. This may be

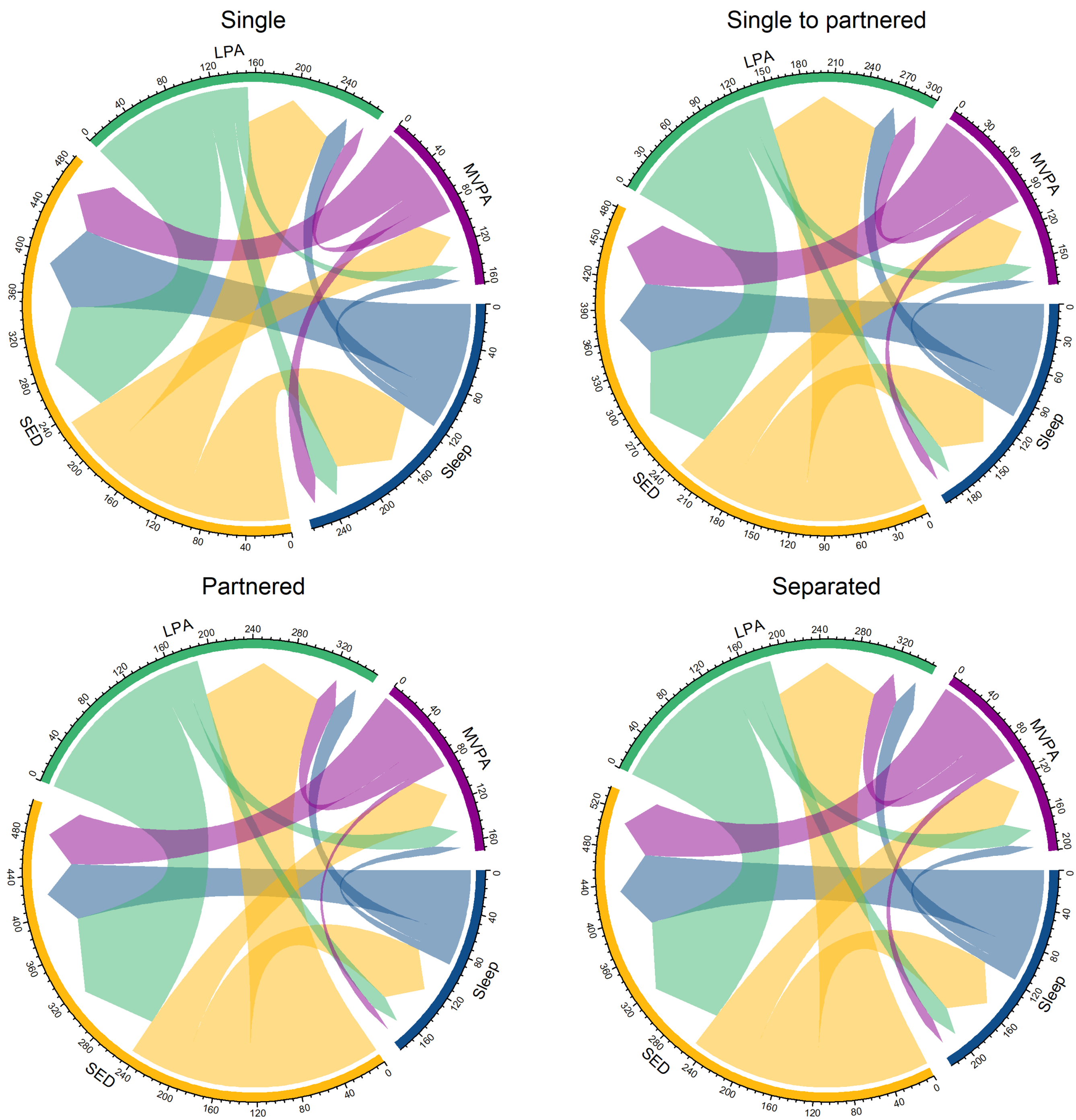

FIGURE 1 | Chord diagram of time flow from baseline to follow-up between each 24-h movement behavior by the relationship groups. For instance, among Single to partnered, 52 min/day flowed from SED to MVPA, and 65 min/day flowed back from MVPA to SED, leading to a net time flow from MVPA to SED by 13 min/day.

relevant, because changes in 24-h movement behaviors during relationship and parenthood transitions may be more pronounced just after the life transition and attenuate after some time has passed. For instance, during the first months after having a baby, sleep may be compromised to a higher extent due to night-time feeding of the baby, and sleep patterns may normalize as a child ages. The relatively long time window between our measurements may also explain why contrary to our hypothesis, we did not observe notable changes in sleep duration among new parents, although a marked drop in self-reported sleep has been observed in previous research [14]. Moreover, changes in 24-h movement behaviors are likely different when comparing time points before and after having a child, depending on whether a parent is on parental leave or, for example, in working life. Furthermore, regarding the follow-up time window, we were unable to investigate in detail the effect of child's age on parents' movement behaviors. Younger children may interfere parents' time use more than older children [38]. In a previous longitudinal study, it was observed that the proportion of the parents meeting physical activity recommendations dropped shortly after becoming a parent but increased in the later years of parenthood [39]. We also observed that those already parents

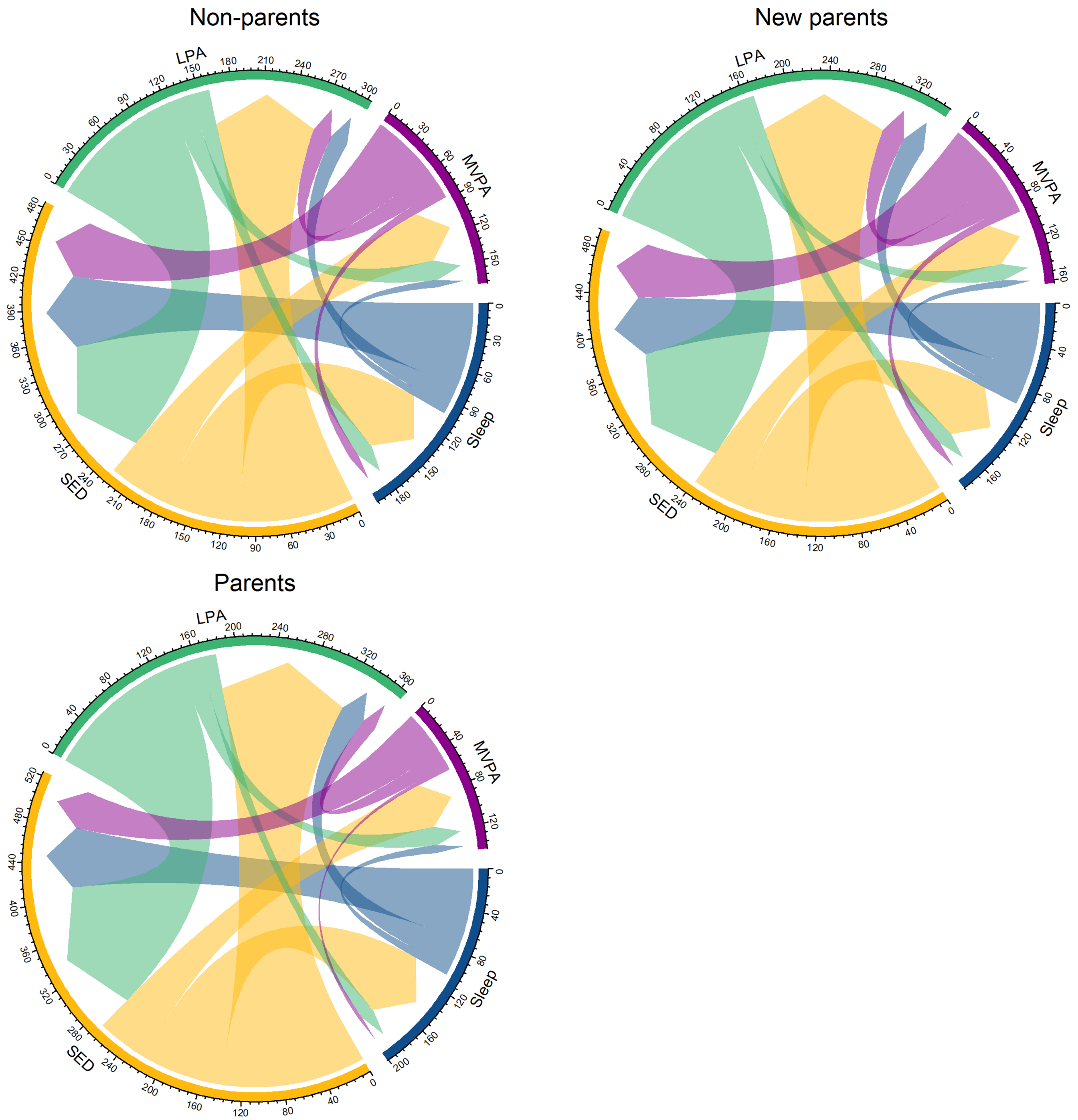

FIGURE 2 | Chord diagram of time flow from baseline to follow-up between each 24-h movement behavior by the parenthood groups. For instance, among New parents, 44 min/day flowed from SED to MVPA, and 59 min/day flowed back from MVPA to SED, leading to a net time flow from MVPA to SED by 15 min/day.

at baseline had lower MVPA level compared to non-parents at baseline, but increased their MVPA during the 5-year follow-up, which seems to support the earlier findings. Therefore, further studies with larger sample sizes and shorter measurement intervals are warranted to capture better both short-term and long-term changes in 24-h movement behaviors across relationship and parenthood transitions.

Our study highlights that relationship and parenthood transitions may change young adults' activity behavior and suggests the importance of considering these life transitions when promoting physically active lifestyle among young adults. These life transitions could also be used as a window of opportunity to intervene young adults' 24-h movement behaviors. Especially new parents may benefit from support to replace some sedentary activities with MVPA to prevent the substantially high drop in MVPA after becoming a parent. This may require additional effort because childcare and household chores take time and resting and napping are needed if night-time sleep quality decreases. However, supporting parents' physical activity can be seen as a long-term investment in the whole family's healthy physical activity patterns, as active parents and parental support for physical activity determine physical activity across a child's later life [40]. Similarly, encouraging those starting a relationship to engage in MVPA instead of sedentary activities could support the physical activity habits of several people at once.

The major strengths of this study are a longitudinal study design and the use of device-based measurements of 24-h movement behaviors that are not subject to recall and information bias [15]. Moreover, we used state-of-art statistical methods to examine changes in 24-h movement behaviors, CoDA, which addresses the co-dependency between these behaviors [18–20], and time flow analysis [36], which enables illustration of how time is reallocated between 24-h movement behaviors.

Our study naturally has some limitations. The study population was drawn from the STRIP study cohort, which was not originally designed to address the research questions of the current study. Therefore, we were unable to construct and recruit the study population (e.g., required sample size) for the current study only. The relatively small study sample increases the risk of type II errors (failure to identify significant association that exists) [41]. However, despite the relatively small sample size, we were able to find statistically significant differences in changes in 24-h movement behaviors within the relationship and parenthood groups. It was not feasible to examine the combined effect of both relationship and parenthood transitions as there were so few of those experiencing both life transitions simultaneously. Becoming a parent may interact with or mediate the association between starting a relationship and physical activity [38], but a recent study suggests that the effect of cohabitation/marriage on physical activity is not completely mediated by becoming a parent [8]. Further considering the size of the study sample, we were unable examine changes in 24-h movement behaviors across relationship and parenthood transitions separately among women and men. Some previous studies have found sex differences in changes of self-reported physical activity, sitting and sleep across relationship and parenthood transitions [12, 14, 42], but former Finnish studies have not found such differences [10, 39]. Given that a partner's habits may influence an individual's 24-h movement behaviors after starting or ending a relationship, information on the partner's 24-h movement behaviors could have further elaborated the observed associations. Also, some methodological limitations should be taken into account as wrist-worn accelerometers have inherent limitations to capture some types of physical activity, such as cycling and weightlifting, and to separate standing from sitting, which may lead to some inaccuracy in the daily estimates of 24-h movement behaviors [43]. However, possible inaccuracy in the absolute values of 24-h movement behaviors should not influence the interpretation of the findings, because we focused on relative, intra-individual changes in the whole 24-h movement behavior composition rather than absolute values of each 24-h movement behavior. Our results may be affected by the national restrictions during the COVID-19 pandemic, as the follow-up measurements were conducted between May 2021 and February 2022.

Finally, the study population comprised Finnish participants of an infancy-onset long-term dietary counseling-based intervention study, possibly attracting in the first place more families who were interested in their health habits. In addition, the current study population was physically more active, and there were more women when compared to those who were lost to follow up. Moreover, since several societal and cultural factors influence activity behavior, the generalizability of our findings may be limited to physically active population subgroups and countries with similar cultures, societal norms, and family policies as in Finland.

5 | Perspective

Only a few previous studies have utilized device-based measures to examine how common life transitions in young adulthood, relationship, and parenthood transitions modify physical activity and SED. These studies have reported decreases in daily total physical activity after starting a relationship and decreases in MVPA and SED after becoming a parent. However, it is unknown how all 24-h movement behaviors, that is, not only physical activity and SED but also sleep, and their interrelationship change during these life transitions. This study utilized repeated 24-h accelerometer measurements across relationship and parenthood transitions and CoDA to examine how the composition of 24-h movement behaviors changed during these life transitions. Our findings showed that physical activity tended to decrease relative to SED and sleep in early adulthood but relationship and parenthood transitions modified these changes. Becoming a first-time parent and starting a relationship was associated with replacement of MVPA with SED. Our study suggest that the aforementioned life transitions should be considered when providing guidance for maintaining physically active lifestyle.

Author Contributions

S.R., J.V., T.R., H.N., O.R., and K.P. designed the longitudinal STRIP study including the follow-up at the age of 26 years. K.P. and S.S. designed the accelerometry data collections. K.S. conducted the analyses with the help of C.L.R. and J.P. K.S. drafted the manuscript. All authors contributed to data interpretation, revised article critically, and approved the final version of manuscript.

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Ethics Statement

The study has been approved by the Joint Commission on Ethics of Turku University and Turku University Central Hospital (51/1801/2014).

Consent

Written informed consent was obtained from parents at study entry, and from the participants at the ages of 15, 18, 26, and 31 years.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Selected variables and their descriptions without personal identification codes are distributed to investigators and collaborators working on specific projects. The rights to the data belong to the STRIP research group.

Data sharing outside the STRIP group requires a data sharing agreement. Investigators can submit an expression of interest to the STRIP Steering Committee.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.