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Increase in physical activity is associated with an increase in sleep efficiency, but not with improvement in symptoms of PTSD: analysis of longitudinal data in trauma-affected refugees

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Abstract

Background In trauma-affected refugees with posttraumatic stress disorder (PTSD), research on physical activity is scarce. Knowing more about the relation between physical activity and PTSD symptoms may provide insight into physical activity as a possible target in the treatment of PTSD. The aim of the present study was to examine whether baseline and change in level of physical activity from baseline to end of treatment were related to, respectively, baseline and change in PTSD symptoms, quality of life, sleep quality, and sleep efficiency in trauma-affected refugees.

Methods Longitudinal data from a randomized controlled trial were analysed with multiple linear regression. Level of physical activity and sleep efficiency were measured with actigraphy and symptoms of PTSD, sleep quality, and quality of life were measured with self-report questionnaires.

Results A higher level of physical activity was significantly associated with better baseline sleep quality, borderline associated with quality of life, but not with symptoms of PTSD, or sleep efficiency. Furthermore, an increase in level of physical activity was significantly associated with improvement in sleep efficiency. Change in level of physical activity was not significantly associated with improvement in PTSD symptoms, quality of life, or sleep quality.

Conclusion The novelty of the current study lies in the finding of no relation between a change in level of physical activity and a change in symptoms of PTSD. The results point to a complex relation between sleep, physical activity and PTSD and point towards a need for studies on these relations to provide effective interventions in trauma-affected refugees.

Trial registration ClinicalTrials.gov ID (NCT02761161), April 27, 2016.

Keywords Physical activity, Sleep quality, PTSD, Quality of life, Refugees

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Background

Globally, the number of refugees has increased during the last decade reaching an unprecedented 35.3 million by the end of 2022 [1]. Furthermore, the Russian invasion of Ukraine has forced over 8 million refugees to flee from Ukraine [2]. A refugee is defined as an individual who "owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country" [3]. Refugees are at high risk of posttraumatic stress disorder (PTSD) as a consequence of traumas, such as imprisonment, torture, combat experience, violent sexual assault, and the violent death of relatives. Post-migration risk factors, such as separation from family members and poor socioeconomic conditions, unemployment, and social isolation may contribute to the development of mental disorders. PTSD prevalence in refugees is estimated to be around 30% [4, 5].

With the rapid increase in the number of refugees during the last decade and the absolute number of refugees with PTSD in high-income countries increasing, appropriate and effective treatment interventions in mental health care services are highly warranted [6–10]. Several meta-analyses have been published on psychosocial interventions for trauma-affected refugees suggesting that interventions such as Cognitive Behavioral Therapy (CBT), Narrative Exposure Therapy, and Eye Movement Desensitization and Reprocessing can reduce symptoms of PTSD. However, analyses also conclude that considerable heterogeneity exists between studies indicating that the efficacy may vary significantly and that significant numbers of refugees continue to show symptoms at end of treatment [6, 7, 11–16].

Poor sleep quality —including difficulties initiating or maintaining sleep and nightmares are part of the diagnostic criteria for PTSD [10, 17]. However, standard PTSD treatment has not traditionally addressed sleep quality, and poor sleep quality often persists after PTSD treatment [17]. In attempts to enhance treatment outcomes, different treatment modalities have been examined focusing on different aspects of PTSD symptomatology. Meta-analyses and reviews find that physical activity and exercise training show promising results in the treatment of PTSD symptoms including sleep quality in non-refugee populations with PTSD [18–21].

In the specific population of refugees, research on physical activity is scarce. Previously, a randomized controlled trial (RCT) has examined the effects of physical activity in trauma-affected refugees and another RCT has examined the effect of group-based physiotherapy intervention in trauma-affected refugees, both identifying no significant effect on symptoms of PTSD [22, 23]. However, a cross-sectional study with a large sample of asylum seekers has identified low level of self-reported physical activity to be associated with higher PTSD symptom severity [24].

Several studies with non-refugee populations have examined the relationship between PTSD symptom severity and level of physical activity, in cross-sectional studies, delineating mixed results [25]. A review found half of the included studies to report a significant association between PTSD and physical activity, and the other half reported no significant associations between PTSD and physical activity [25]. The studies reporting a significant association identified that participants with PTSD reported significantly less vigorous physical activity, more infrequent physical activity, and that fewer participated in weekly physical activity [26–28]. Furthermore, increased engagement in vigorous physical activity was significantly associated with reduced odds of having new-onset symptoms and/or persistent PTSD symptoms [26].

Most studies on physical activity and symptoms of PTSD rely on self-reported data and are cross-sectional in design. Studies using technical measures for physical activity and longitudinal studies are called for [25, 29]. There is a lack of studies on the relationship between changes in the level of physical activity and PTSD symptoms in trauma-affected populations, in general terms, and no such studies in the specific population of refugees. Furthermore, previous research has suggested a role of physical activity in relation to both self-reported aspects such as quality of life, and sleep quality and technical measures concerning sleep, such as sleep efficiency [20, 29–31]. However, to the best of our knowledge, these relations have not been examined in a population of trauma-affected refugees. Knowing more about the relation between change in the level of physical activity over time and treatment response for PTSD symptoms, quality of life, quality of sleep, and sleep efficiency, may provide insight on the relation between physical activity, sleep and PTSD, in general, and in the specific population of trauma-affected refugees.

The aim of the present study was therefore to examine whether:

- Baseline level of physical activity was related to baseline PTSD symptoms, quality of life, sleep quality, and sleep efficiency in a population of trauma-affected refugees.
- change in the level of physical activity from baseline to end of treatment was related to changes in PTSD symptoms, quality of life, sleep quality, and sleep efficiency from baseline to end of treatment in a population of trauma-affected refugees.

Methods

Study design and participants

We analysed data from refugees with PTSD having participated in a RCT performed at the Competence Centre for Transcultural Psychiatry (CTP) in the period 2016–2019 [32, 33]. The study design and the data collection methods have been described in detail elsewhere [32, 33].

Participants were adult refugees diagnosed with PTSD who provided written informed consent for study participation. Inclusion criteria were PTSD diagnosis according to ICD-10 determined in a clinical interview, poor sleep quality measured as a score > 8 on the Pittsburgh Sleep Quality Index, and nightmares measured as a score ≥ "a little" on the Harvard Trauma Questionnaire nightmare item. Exclusion criteria were severe psychotic disorder, a current alcohol or drug use disorder, a neurodegenerative disorder or an acute need of admission to a psychiatric inpatient facility.

The overall aim of the RCT was to estimate treatment effects in trauma-affected refugees. The participants were randomized to one of four intervention groups. All four groups received treatment-as-usual (TAU) consisting of a 10–12 months bio-psycho-social interdisciplinary treatment approach, including manual-based CBT, physiotherapy, pharmacological treatment according to standard and best clinical practice in the field (sertraline is first-choice antidepressant, venlafaxine second-choice antidepressant), psychoeducation, and social counselling within a frame of weekly sessions with a physician, a physiotherapist, a social counsellor, or psychologist.

One group received solely TAU to serve as a control group, while the three remaining groups were active treatment groups, receiving add-on treatment with either Imagery Rehearsal Therapy (IRT) (CBT focusing on nightmares) and/or mianserin (a sedative antidepressant), or a combination of both. The RCT identified no between-group differences in symptoms of PTSD, sleep quality or quality of life at baseline, end of treatment or from baseline to end of treatment [32, 33], and the current study examined the complete sample across intervention groups regardless of which treatment the participants received.

Measures

In an initial assessment interview sociodemographic information was collected, including among other factors age, level of education and affiliation to the labour market. Baseline status and treatment response was evaluated using both self-administered rating scales and observer ratings. Symptoms of PTSD were assessed with the self-reported Harvard Trauma Questionnaire (HTQ), consisting of 16 items with a score range from 1 to 4 [34, 35]. HTQ is the most prevalent scale for evaluating PTSD symptoms in refugees. The HTQ has been developed in refugee research and the scale is perceived as reliable in a clinical refugee sample [36, 37]. Quality of life was measured by self-report on the WHO-5, consisting of five questions with a score range from 0 to 5 [38]. Sleep quality was measured on the Pittsburgh Sleep Quality Index (PSQI), consisting of 19 items and measuring seven components of Sleep. The component scores each have a range of 0–3 points and they are added to yield one global PSQI score with a score range from 0 to 21 [39, 40].

Actigraphic assessment

The participants wore an Actiwatch Spectrum (Philips Respironics) device on their non-dominant wrist for 24 h a day for 14 consecutive days at baseline and at end of treatment. An Actiwatch measures wrist movement, and can be used to measure physical activity and sleep patterns [41, 42].

Activity counts were logged for 30-second epochs and stored in Actiware (version 6.0.9, Respironics, Murrysville, PA, USA) format files. For the analyses, data were processed to calculate activity per minute, hour, and 24 h. Actigraphy data were used to calculate the mean activity score per hour, during the most active 10-hour period (M10, counts/hour) per 24-h day to represent the mean level of daytime physical activity [41–43]. Furthermore, Actiware Version 6.0.9 Philips Respioronics 2020 was used to analyze sleep data. An automatic algorithm determined sleep and wake states and thus calculated sleep efficiency (SE).

Actigraphy data were excluded for participants with fewer than 7 days of recording to increase the reliability of the actigraphy measures [44]. Actigraphy data for participants with a minimum of 7 days' measurements, each day with a minimum of 10 h of recording during wake time and a maximum of 1-hour non-recording during sleep time, for any of the recorded 7 days were included. All actograms were visually screened for sufficient wear time before being submitted for analysis. The data were cleaned manually by the first author according to prespecified editing rules. Event markers, activity counts, diary information and light input were used to adjust the start and end time points of the rest intervals, if necessary. Baseline actigraphy measures were included for 118 participants and baseline to end of treatment actigraphy measures were included for 54 participants.

Differences in the level of symptoms and sociodemographic characteristics were tested for between participants with and without actigraphy measures and between participants with and without end of treatment scores. We identified no significant differences in the level of symptoms or sociodemographic characteristics and missing actigraphy data were deemed at random.

Statistical analysis

To describe the sample characteristics, means, and standard deviations (SD) were calculated for continuous variables, and percentages were calculated for categorical variables. Mean rating scores were calculated for baseline and end of treatment measures, and significant baseline to end of treatment differences were tested for with paired t-test.

A baseline to end of treatment variable was created displaying the difference in score between baseline score and end of treatment score.

In a multiple linear regression model, we tested whether the baseline level of daytime physical activity (exposure variable) was associated with baseline severity of PTSD, quality of life, sleep quality, and sleep efficiency (dependent variables). Baseline scores corresponding to the dependent variable, age, and sex were included as confounder variables.

Table 1 Sociodemographic characteristics of sample ($N=219$, except where noted)

	Mean (SD)
Age (years)	44.44 (10.40)
Years since arrival in Denmark ($n=211$) *	13.33 (9.55)
	***n*(%)**
Female	110 (50)
Male	109 (50)
Country of origin ($n=207$)*	
Afghanistan	26 (13)
Iran	19 (9)
Iraq	54 (26)
Lebanon	15 (7)
Syria	58 (28)
Other	35 (17)
Psychosocial status	
Needing translator during medical doctor sessions ($n=189$)*	119 (63)
Affiliation to the labour market / studying ($n=183$)*	66 (36)
Income from labour ($n=196$)*	13 (7)
Living alone all the time ($n=198$)*	28 (14)
Having children of < 18 years of age ($n=160$)*	130 (80)
Education > 10 years from home country ($n=165$)*	86 (52)
Work experience in Denmark ($n=197$)*	96 (48)
Smoking ($n=185$)*	67 (36)
Diagnoses (ICD-10)	
PTSD	219 (100)
Depression	157 (72)

SD, standard deviation

ICD-10, International Classification of Disease

PTSD, posttraumatic stress disorder

*Data not available for all randomized participants

In a multiple linear regression model, we tested whether change in the level of physical activity (exposure variable) was associated with change in the severity of PTSD, quality of life, sleep quality, and sleep efficiency. Baseline scores on the corresponding dependent variable, age, and sex were included as confounder variables.

We performed multiple linear regression analyses using STATA's SEM procedure, applying a Full Information Maximum Likelihood (FIML) analysis to handle missing data. FIML estimates a likelihood function for each individual based on the present variables in order to use all available data, including data for participants with missing end of treatment scores.

To check assumptions of linearity, a scatterplot of the included variables was plotted with a superimposed regression line. Visual inspection of these plots indicated a linear relationship between the continuous variables and no outliers of importance. Independence of errors, homoscedasticity, and normality of residuals was met to a reasonable degree.

Statistical analyses were conducted using Stata version 14.1 for windows.

Results

The study included 219 participants with a mean age of 44.4 years (SD 10.4). There were 110 (50%) female participants. Sociodemographic characteristics are presented in Table 1.

Mean scores at baseline, end of treatment, and differences from baseline to end of treatment for PTSD symptoms, quality of life, sleep quality, physical activity, and sleep efficiency are presented in Table 2. We found a significant improvement in PTSD symptoms, quality of life, sleep quality, and a significant decrease in sleep efficiency. No differences were seen in the level of physical activity. However, the standard deviation for change score for level of physical activity is quite large with values spread out from the mean, exhibiting large variation in change in level of physical activity.

Table 3 presents the results of the multiple linear regression analyses on baseline values adjusted for age and sex.

We found that the baseline level of physical activity was significantly associated with sleep quality (β = -0.33, $p<0.000$). The baseline level of physical activity was borderline associated with baseline quality of life ($\beta=0.20$, $p=0.053$), but not significantly associated with the severity of PTSD symptoms, or sleep efficiency.

Table 4 presents the results of the multiple linear regression analyses on change values controlled for baseline score on the corresponding dependent variable, adjusted for age and sex. Change in the level of physical activity was significantly associated with improvement in sleep efficiency ($\beta=0.40$, $p=0.002$). The model accounted

Table 2 Mean scores at baseline and end of treatment for self-reported PTSD symptoms (HTQ), quality of sleep (PSQI), quality of life (WHO-5), actigraphy-derived activity count (M10) and sleep efficiency (SE)

Rating	Mean score (SD) baseline	Mean score (SD) end of treatment	Difference baseline-end of treatment	*p*-value difference baseline-end of treatment
Self-reported				
HTQ, *n* = 159	3.14 (0.41)	2.95 (0.62)	-0.18 (0.59)	**< 0.0001***
PSQI, *n* = 154	16.35 (2.69)	14.53 (4.29)	-1.82 (4.27)	**< 0.0001***
WHO-5, *n* = 146	17.25 (16.39)	25.18 (23.07)	7.94 (21.68)	**< 0.0001***
Actigraphy measures				
M10, *n* = 54	267.13 (85.65)	268.43 (89.83)	1.30 (63.18)	0.880
SE, *n* = 55	80.80 (6.88)	79.38 (6.94)	-1.41 (5.09)	**0.045***

Raw baseline and end of treatment scores and score differences for ratings for participants for which both baseline and end of treatment scores are available

SD = Standard deviation

* = Statistically significant improvement

HTQ, Harvard Trauma Questionnaire: 1–4 (1 best score), PSQI Pittsburgh Sleep Quality Index: 1–21 (1 best score), WHO-5 Well Being Index: 1-100 (100 best score), M10, mean activity score of the most active 10-hour period, measured in counts/hour; SE Sleep efficiency, measured in %

for 28% of the variance (R^2) in treatment response for sleep efficiency. Change in the level of physical activity was not statistically significantly associated with improvement in the severity of PTSD symptoms, quality of life, or sleep quality.

The adjustment for age and sex lends to minor numerical changes in the estimates with no impact on the level of significance, nor overall conclusion. We tested for and found no confounding influences of employment in any of the models (data not shown).

Discussion

The main findings of this study were that a higher daytime level of physical activity was significantly associated with better baseline sleep quality, borderline associated with quality of life but not with symptoms of PTSD, or sleep efficiency. Furthermore, change in the level of physical activity during the intervention added statistically significantly to the prediction of improvement in sleep efficiency. However, change in the level of physical activity did not add statistically significantly to the prediction of improvement in PTSD symptoms, quality of life, or sleep quality.

Physical activity and symptoms of PTSD

This examination of the association between the level of physical activity and PTSD adds to a growing body of literature on the relation between the two [25, 29, 31]. The current study did not identify a significant relation between the baseline level of physical activity and

Table 3 Multiple regression analyses of baseline level of physical activity on PTSD symptoms (HTQ), quality of sleep (PSQI), quality of life (WHO-5), and sleep efficiency (SE) adjusted for age and sex

	HTQ				PSQI				SE				WHO-5			
	β	95% CI for β		*p*	R^2	β	95% CI for β		*p*	R^2	β	95% CI for β		*p*	R^2	β	95% CI for β		*p*	R^2
		LL	*UL*				*LL*	*UL*				*LL*	*UL*				*LL*	*UL*		
					0.04					0.14					0.04					0.06
Age	0.08	-0.06	0.23	0.272		0.05	-0.10	0.19	0.534		0.01	-0.18	0.19	0.359		-0.12	-0.27	0.04	0.129	
Sex	0.11	-0.03	0.24	0.112		**0.18**	**0.05**	**0.31**	**0.009***		**0.17**	**0.01**	**0.34**	**0.039***		-0.01	-0.14	0.12	0.854	
M10	-0.15	-0.36	0.06	0.161		**-0.33**	**-0.51**	**-0.15**	**< 0.001***		0.08	-0.09	0.25	0.359		0.20	-0.00	0.41	0.053	

β = standardized coefficient, CI = confidence intervals, *LL* = lower limit, *UL* = upper limit, R^2 = Adjusted R-square for full model

Statistically significant associations ($p < 0.05$) are indicated in bold and with an *

HTQ, Harvard Trauma Questionnaire (1 best score), *PSQI* Pittsburgh Sleep Quality Index (1 best score), WHO-5 Well Being Index (100 best score), *M10*, mean activity score of the most active 10-hour period, measured in counts/hour; *SE* Sleep efficiency, measured in %

Table 4 Multiple regression analyses of change in level of physical activity on change in PTSD symptoms (HTQ), quality of sleep (PSQI), quality of life (WHO-5), and sleep efficiency (SE) adjusted for baseline score, age and sex

	HTQ					PSQI					SE					WHO-5				
	β	95% CI for β		*p*	R^2	β	95% CI for β		*p*	R^2	β	95% CI for β		*p*	R^2	β	95% CI for β		*p*	R^2
		LL	*UL*				*LL*	*UL*				*LL*	*UL*				*LL*	*UL*		
					0.12					0.18					0.28					0.13
Baseline score	**0.29**	**0.12**	**0.44**	**0.001***		**0.37**	**0.22**	**0.52**	**< 0.0001***		**0.28**	**0.10**	**0.45**	**0.002***		**0.28**	**0.12**	**0.043**	**0.0001***	
Age	**-0.22**	**-0.37**	**-0.07**	**0.005***		**-0.24**	**-0.42**	**-0.06**	**0.008***		-0.06	-0.32	0.19	0.625		**0.23**	**0.06**	**0.40**	**0.006**	
Sex	0.00	-0.16	0.16	0.993		0.02	-0.14	0.14	0.978		-0.02	-0.26	0.22	0.866		-0.07	-0.24	0.09	0.373	
M10	-0.15	-0.54	0.24	0.452		-0.06	-0.26	0.31	0.868		**0.40**	**0.15**	**0.64**	**0.002***		0.08	-0.23	0.38	0.613	

β = standardized coefficient, CI = confidence intervals, *LL* = lower limit, *UL* = upper limit, R^2 = Adjusted R-square for full model

Statistically significant associations ($p < 0.05$) are indicated in bold and with an *

HTQ, Harvard Trauma Questionnaire (1 best score), *PSQI* Pittsburgh Sleep Quality Index (1 best score), WHO-5 Well Being Index (100 best score), *M10*, mean activity score of the most active 10-hour period, measured in counts/hour; *SE* Sleep efficiency, measured in %

symptoms of PTSD, replicating results from a review where half of the included studies reported no significant associations between PTSD and physical activity but diverging from the other half reporting a significant association between PTSD and physical activity [25]. The novelty of the current study lies in the finding of no relation between a change in the level of actigraphy measured physical activity and a change in symptoms of PTSD.

A previous study has shown a significant correlation between time spent walking and symptoms of PTSD, whereas the study did not find a correlation between self-reported moderate or vigorous physical activity and PTSD symptoms [45] possibly due to the limitations of self-report measures in comparison with technical measures of the intensity of physical activity. The current study lacks data on moderate or vigorous physical activity. In a previous publication, on the current sample, we highlighted the importance of leaving the house daily, contact with social networks, and exposure to daylight as important factors in relation to PTSD symptoms and circadian rhythm [46]. It is possible that the positive effect of time spent walking on symptoms of PTSD may also be related to leaving the house, contact with social networks, and exposure to daylight, and not merely the additional physical activity. Previous studies found no effect of physical activity interventions in trauma-affected refugees [22, 23].

One reason highlighted for the absence of effect of these interventions in refugees is a lack of previous experience with physical activity and unfamiliarity with the impact of physical activity on the body, such as pain in muscles after vigorous physical activity [22, 23]. We suggest further research to investigate the effect of interventions in trauma-affected refugees focusing on psychical activity in terms of both moderate and vigorous physical activity and on the role of activities enhancing both physical activity and activities outside the household, exposure to daylight and engagement in social networks. Furthermore, we suggest further research to study the effect of interventions in relation to both sexes and to include technical measures of sleep and physical activity [47].

Physical activity and quality of life

A recent meta-analysis found a small but significant effect of physical exercise on the self-reported quality of life in populations with PTSD [20]. In the current study, we found an association between the baseline level of physical activity and quality of life, but did not identify a relation between an increase in the level of physical activity and an improvement in the quality of life. It is somewhat surprising that the baseline relation between the level of physical activity and quality of life is not replicated in the

relation between the change in the level of physical activity and the change in the quality of life. However, it is in line with the prior mentioned study examining the effect of physical activity in trauma-affected refugees, which likewise found no intervention effect on quality of life [22].

Physical activity and sleep parameters

In accordance with previous studies in PTSD populations, we found an association between higher physical activity levels and better baseline sleep quality [29, 31, 45, 48]. However, we did not identify a relation between an increase in the level of physical activity and an improvement in sleep quality. Contrary to these findings, while we identified no baseline relation between the level of physical activity and sleep efficiency, we found that an increase in the level of physical activity was significantly related to an increase in actigraphy measured sleep efficiency. The relation between a high level of physical activity and high sleep efficiency has previously been identified in the general population [30], but has, to our knowledge, not previously been studied in populations with PTSD, nor among refugees.

The cross-sectional design of both the current and previous studies does not allow for conclusions concerning the directionality of the relation. Physical activity may result in a higher sleep pressure and thus improve sleep, and poor sleep may cause daytime fatigue and less energy for physical activity [29].

Several meta-analyses have delineated interesting findings concerning the role of sleep in relation to PTSD [21, 49, 50]. A lower sleep efficiency has been identified in populations with PTSD compared to healthy controls, suggesting a promising effect of increasing sleep efficiency in order to improve PTSD symptoms [50]. The effect of exercise training on overall sleep quality among small samples of individuals with PTSD suggests that exercise training can improve overall sleep quality for those with PTSD [21], and a meta-analysis of the effects of physical activity on sleep in mixed populations found that regular exercise affected both sleep quality and sleep efficiency [49].

Current guidelines on the treatment of sleep disturbances in PTSD recommend cognitive-behavioral therapy for insomnia (CBT-I) [17], focusing on sleep cognitions, stabilizing sleep by sleep-wake schedule, including, among others, stimulus control strategies and regularity of rise- and bedtime to improve sleep efficiency. However, the identified relation between increase in the level of physical activity and an increase in sleep efficiency suggests an interesting shift in focus to daytime activity as a possible factor in interventions seeking to improve sleep efficiency.

Thus, the current findings support recommendations in our previous publication suggesting that interventions focusing on social rhythm regularity established by employment, activities encouraging leaving the house during the day and in daylight, as well as social networking, may likewise increase physical activity– and subsequently potentially also sleep efficiency [46]. Furthermore, regular daily activities may eliminate sleep-disruptive behaviors, such as late rising and napping, that interfere with the overall sleep process [51], and may strengthen sleep pressure and impact sleep efficiency and sleep quality.

Strengths and limitations

The use of actigraphy to measure both physical activities and sleep efficiency is a key strength of the current study since self-report measures of physical activity may be impacted by recall bias, variability in the perception of activity intensity, and difficulty quantifying time spent being physically active [52]. Comparisons with previous studies on PTSD and physical activity that rely on self-report measures must be made with caution due to the differences in the methodological approach.

The equal proportions of men and women is a strength of the study due to underrepresentation of women in PTSD studies of military service members and veterans [25]. Furthermore, the use of longitudinal data is a strength. However, causal conclusions on the direction of the associations between change scores are not possible.

Actigraph-wearing compliance was low both at baseline- and at end of treatment, similar to that seen in other studies on populations with PTSD [53], posing a limitation. This limitation is also addressed in the method section. Forgetting to put on the actigraph after a short non-wear period was commonly reported. Feeling trapped and monitored was also noted as reasons, likewise was fear of stigma in the workplace or language school concerning the need for monitoring. Furthermore, it is a limitation that the actigraphy data included in this study does not distinguish between work or leisure time and does not provide knowledge regarding the intensity (low, moderate or vigorous) of the physical activity. Lastly, only small changes were identified from baseline to end of treatment posing a possible limitation.

Conclusions

To our knowledge, this is the first study using actigraphy measures of physical activity in a longitudinal design in a population with PTSD. The study identified an association between an increase in physical activity and an increase in sleep efficiency, but not with improvement in symptoms of PTSD, quality of life, or sleep quality, in a sample of trauma-affected refugees. The relation between increase in the level of physical activity and an increase

in sleep efficiency suggests an interesting shift in focus to daytime activity as a possible factor in interventions seeking to improve sleep efficiency.

The results point to a complex relation between sleep, physical activity and PTSD and a need for studies on these relations to provide effective interventions in trauma-affected refugees. We suggest further research on the effect of interventions on both symptoms of PTSD and sleep parameters, focusing on psychical activity in terms of interventions enhancing exercise and on the context for and the role of activities enhancing both physical activity and activities outside the house, exposure to daylight and engagement in social contact.

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Author contributions
All authors contributed to the study's conception and design. Material preparation, data collection, and analyses were performed by Hinuga Sandahl and Jessica Carlsson. The first draft of the manuscript was written by Hinuga Sandahl. Jessica Carlsson, Mette Korshøj and Ole Steen Mortensen commented on subsequent versions. All authors read and approved the final manuscript.

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Data availability
The data supporting this study's findings are available from the corresponding author on reasonable request.

Declarations

Ethics approval
The authors assert that all procedures were carried out in accordance with the ethical standards of the National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol and amendments were approved by the Ethics Committee of the Capital Region of Denmark (H-15014503), the Danish Medicines Agency (EudraCT: 2015-004153-40) and the Danish Data Protection Agency (2012-58-0004).

Consent for publication
Not applicable.

Consent to participate
All participants gave written informed consent prior to participation.

Competing interests
The authors declare that they have no competing interests.

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