DEVELOPMENT AND EVALUATION OF A MOBILE HEALTH INTERVENTION TO IMPROVE PHYSICAL ACTIVITY AND SLEEP HEALTH IN ADULTS: THE SYNERGY STUDY

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DEVELOPMENT AND EVALUATION OF A MOBILE HEALTH INTERVENTION TO IMPROVE PHYSICAL ACTIVITY AND SLEEP HEALTH IN ADULTS: THE SYNERGY STUDY

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I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any University or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo.

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I hereby certify that the work embodied in this thesis contains published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written declaration endorsed in writing by my supervisors, attesting to my contribution to the joint publication/s/scholarly work.

Beatrice Murawski

19/04/2019

Acknowledgement by the Supervisors

By signing below, I confirm that Beatrice Murawski contributed as follows to the published paper/s/scholarly work presented in Chapters 3 through 7, for which I am a co-author.

For all publications/scholarly work, where applicable, Beatrice has:

- Contributed to the development of research questions
- Contributed to the conceptualisation of research design and methods
- Contributed to the development and modification of data collection tools
- Managed all data collection procedures
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Chapter 3

Chapter 5

CONFLICT OF INTEREST AND FUNDING

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Five of the eight chapter of this thesis form a series of papers of which I, Beatrice Murawski, am the lead author. At the time of the final submission, three of these papers were published and two papers were under review.

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Oftedal S, Burrows T, Fenton S, **Murawski B**, Rayward AT, Duncan MJ. Feasibility and preliminary efficacy of an m-health intervention targeting physical activity, diet and sleep quality in shift-workers. Int J Env Res Pub He 16(20) (2019) 3810.

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LIST OF ABBREVIATIONS

AAQ	Active Australia Questionnaire
ABS	Australian Bureau of Statistics
ANZCTR	Australian New Zealand Clinical Trials Registry
ARIA	Accessibility and Remoteness Index of Australia
BCF	Baseline carried forward
BCTs	Behaviour change techniques
BMI	Body mass index
CAMPUS	Cognitive-Affective Model of Perceived User Satisfaction
CBT-I	Cognitive Behavioural Therapy for Insomnia
CG	Control group
CHD	Coronary heart disease
CI	Confidence interval
CVD	Cardiovascular disease
DALY	Disability-adjusted life years
EM	Expectation Maximisation
ESS	Epworth Sleepiness Scale
GLMM	Generalised linear mixed models
GP	General practitioner
HR	Hazard ratio
HREC	Human Research Ethics Committee
HRQOL	Health-related quality of life
ICC	Intra-class correlation coefficient
ICTRP	International Clinical Trials Registry Platform
IG	Intervention group
ISI	Insomnia Severity Index
KMO	Kaiser-Meyer-Olkin
LPA	Light physical activity
M	Mean
MET	Metabolic Equivalents of Task
MOS-SLP9	Medical Outcomes Study Sleep Problem Index-II
MVPA	Moderate-to-vigorous intensity physical activity
NHANES	National Health and Nutrition Examination Survey

OSA	Obstructive sleep apnoea
OR	Odds ratio
PA	Physical activity
PCA	Principal component analysis
PMR	Progressive muscle relaxation
PRCPAN	Priority Research Centre for Physical Activity and Nutrition
PSQI	Pittsburgh Sleep Quality Index
QOL	Quality of life
QWB	Quality of well-being
RCT	Randomised controlled trial
RR	Risk ratio
RSS	Research Student Support
RT	Resistance training
SCT	Social Cognitive Theory
SD/SE	Standard deviation/standard error
SHI	Sleep Hygiene Index
SMD	Standardised mean difference
SOL	Sleep onset latency
STEPS	Sleep Treatment and Education Program for Students
TST	Total sleep time
VPA	Vigorous physical activity
WASO	Wake after sleep onset
WHO	World Health Organization

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THESIS ABSTRACT

Background

Large proportions of the adult population report insufficient physical activity and poor sleep health in the absence of a clinical sleep disorder. Both behaviours have a substantial impact on overall health and well-being and are thought to share a bi-directional relationship. This implies insufficient physical activity and poor sleep health should be targeted in combination. Intervention strategies that are delivered using mobile health (m-health) solutions show promising effects and improve the reach of behaviour change interventions to improve public health. To date, there is no published evidence to show that an m-health trial to improve physical activity and sleep health in combination would be efficacious. Though key to the development of such a trial, no previous reviews have compiled the evidence from sleep interventions with particular focus on adults who report poor sleep health without a clinically-diagnosed sleep disorder. Moreover, there is limited understanding of the psychosocial mechanisms in a behaviour change intervention targeting multiple behaviours, and there are no instruments available to measure these mechanisms in the context of sleep health.

Objectives

To address these gaps, the thesis had one primary aim and three related secondary aims. The primary thesis aim was to test the efficacy of a theory-based m-health intervention (The Synergy Study) to improve physical activity and sleep quality in adults. The three secondary thesis aims were: (1) to review the evidence from studies that have examined the effectiveness of cognitive and behavioural interventions to improve sleep health in adults without sleep disorders; (2) to develop and test the psychometric qualities of an instrument for the assessment of the psychosocial determinants of sleep hygiene practice; and, (3) to examine potential mediators of changes in physical activity, sleep quality and sleep hygiene in the Synergy Study.

Methods and Results

Primary Aim (Chapter 6)

The Primary Aim was investigated in the Synergy Study, a two-arm randomised waitlist-controlled trial including 160 Australian adults reporting insufficient physical activity and poor sleep quality at screening. The intervention consisted of a mobile application (referred to as 'app') that was built for participants to utilise educational resources, goal-setting, self-monitoring and feedback strategies. In addition, participants received personalised support including weekly progress reports, tool sheets and prompts for 12 weeks. The primary endpoint of the intervention occurred at three months and participants completed follow-up assessments at six months. All assessments were conducted online using self-report measures. Minutes of moderate-to-vigorous intensity physical activity (MVPA) and sleep quality were co-primary outcomes and the study also assessed a range of secondary outcomes (i.e., resistance training, sitting time, sleep hygiene, sleep timing variability, insomnia severity, daytime sleepiness, quality of life, and depression, anxiety and stress symptoms). Baseline-adjusted between-group differences using complete cases were examined using generalised linear mixed models and logistic regression models. sensitivity analyses were conducted following predicted mean matching and chained equation modelling to impute missing data. The Synergy Study showed that compared to the control group, participants who received the intervention reported significantly better sleep quality at three months ($p = 0.009$), but not at six months. There was no evidence of an intervention effect on MVPA ($p = 0.139$). At three months, significant between-groups differences in favour of the intervention were observed for the following secondary outcomes: resistance training ($p = 0.004$), subjective sleep quality ($p = 0.017$), sleep onset latency ($p = 0.013$), waketime variability ($p = 0.018$), sleep hygiene ($p = 0.027$), insomnia severity ($p = 0.002$) and stress symptoms ($p = 0.003$). At six months, the majority of these differences were maintained, and additional improvements were found for bedtime variability ($p = 0.023$), sleepiness ($p <0.001$), daytime dysfunction ($p = 0.039$) and anxiety symptoms ($p = 0.003$).

Secondary Aim 1 (Chapter 3)

Four major electronic databases were searched using pre-defined search strings to locate original research published as English language full-text. Two reviewers independently

screened and selected eligible articles, extracted data and assessed study quality. The synthesis provided a descriptive summary of study characteristics and quantitative results based on meta-analyses using random-effects models. Combined estimates were presented using Hedge's *g*. Established methods were used to assess between-study heterogeneity (*Q*-statistics, *I*-statistics), publication bias (Rosenthal's classic failsafe *N*) and the impact of unpublished data (Duval and Tweedie's trim and fill method). This study showed that cognitive and behavioural interventions improve sleep quality in adults with poor sleep health who do not have a clinical sleep disorder ($g = –0.54$).

Secondary Aim 2 (Chapter 4)

Existing items to assess the psychosocial determinants (i.e.., self-efficacy, perceived capability, environment, social support, intention and planning) of physical activity and diet were adapted to focus on practices pertaining to sleep hygiene such as keeping regular bed and wake times, reducing the impact of stimuli and exercising regularly. Baseline data from the Synergy Study were analysed to examine scale unidimensionality by way of Principal Component Analyses. Measures of the scales' internal consistency were reported as Cronbach's alphas. A separate sample including 20 participants was recruited to assess levels of test-retest reliability using intra-class correlation coefficients. The new instrument consisted of seven scales and demonstrated acceptable psychometric qualities with good to excellent internal consistency ($\alpha = 0.76–0.92$) and good to excellent test-retest reliability (ICC = 0.61–0.84).

Secondary Aim 3 (Chapter 7)

Using data from the Synergy Study, this aim was addressed in a mediation analysis. For the purpose of this study, missing data were imputed using Expectation Maximisation. A range of psychosocial factors were hypothesised to mediate changes in physical activity, sleep quality and sleep hygiene as a result of the intervention. In addition, physical activity was examined as a behavioural mediator of sleep quality and vice versa; and sleep hygiene as a mediator of changes in sleep quality. Each of the hypothesised causal chains was assessed in a single mediator model. Following Preacher and Hayes' approach to mediation analysis, bias-corrected bootstrapped confidence intervals, calculated using PROCESS 2 for SPSS were used for the interpretation of results. The analyses demonstrated that MVPA was mediated by a number of psychosocial factors (i.e., self-

efficacy, perceived capability, environment, social support, intention and planning). Neither of the two sleep outcomes (sleep quality and sleep hygiene) were mediated by any of the hypothesised psychosocial mediators. There was no evidence for a bi-directional relationship between physical activity and sleep quality. However, sleep hygiene mediated sleep quality.

Conclusion

The thesis presents new findings on how to improve physical activity and sleep health in combination using an m-health intervention that incorporated personalised support, with particular focus on insufficient physical activity and poor sleep health in adults without diagnosed sleep disorders. Furthermore, it provides a new method to assess the psychosocial determinants of sleep hygiene practice, which is key to the promotion of good sleep health; and offers novel insights into the role these psychosocial factors play as mechanisms (mediators) of intervention efficacy in a multiple behaviour change intervention. Supported by the findings arising from the thesis and in the context of previous research, a number of gaps remain to be addressed in future studies. Additional multiple health behaviour trials with potential for wide reach are needed to make health behaviour strategies accessible to a large proportion of the general adult population. These studies should aim to recruit samples that are representative of the general adult population (i.e., increase proportion of male participants and those with low socioeconomic status). More studies with specific focus on individuals with sub-clinical sleep problems are needed to broaden the extent to which the evidence pinpoints effective interventions in this population group. Lastly, the overall understanding of the psychosocial mechanisms of behaviour change in multiple behaviour interventions, the measurement of, as well as investigations into these mechanisms also require additional attention. Taken together, this knowledge could have the potential to improve public health.