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Intended Department	University of South Australia
Project:	"My Best Day for Knee OA" Creation of a web-based app to individualise time-use for people with painful knee osteoarthritis

Scientific summary:
International clinical practice guidelines recommend that first-line treatment of knee osteoarthritis (OA) should consist of non-surgical care.[1] Such treatment includes education, physical activity, and weight management given established benefits for knee OA symptoms and function for all people with knee OA.[1] Clinical guidelines also recommend that treatment is individualised to each person with knee OA, based on their unique sociodemographic profile and current lifestyle.[1] However, prescriptions typically remain general (e.g., 'move more, sit less', or 'complete 150 minutes of moderate-to-vigorous physical activity per week'), with little guidance on how to personalise treatment. Lack of personalised treatment risks suboptimal outcomes. Emerging research suggests that using a 'one-size-fits-all' approach to lifestyle treatments does not improve health outcomes for everyone.[2] Indeed, global recommendations to 'move more, sit less' may actually be detrimental to some people, particularly those of lower socioeconomic status (i.e., working physically demanding jobs).[3]

Adding to the complexity of personalised prescriptions is the fact that every increase in time spent in one health behaviour must be accompanied by an equal compensatory time loss from another health behaviour. For example, a 30-minute increase in daily physical activity must result in a 30-minute decrease in another time-use behaviour, such as sleep or sedentary time. Time-use trade-offs are complex and may have unintended consequences. For example, in children reallocating 60 minutes of time toward physical activity can have diverging impacts depending on the outcome of interest, and what type of activity the time comes from.[4] Trading 60 minutes towards physical activity from screen time alone is associated with reductions in body far and increases in academic performance and psychosocial health. However, if these same 60 minutes are taken from a mix of other behaviours (e.g., sleep, quiet time, and screen time), there may be an associated decrease in academic performance. Exploring time-use trade-offs may be particularly relevant in knee OA, given that both sleep and physical activity are independently related to knee OA

symptoms. That is, both greater time spent sleeping and greater time spent physically active are linked to improved knee OA symptoms.[5,6] Thus, if an increase in time spent physically active results in less sleep, this activity swap may not lead to meaningful changes in knee OA symptoms, or even result in worsening of symptoms.

Compositional time-use analyses address these issues by seeking to understand the inter-dependencies of time-use and potential impact of reallocations of time. These analyses have resulted in the creation of individualised lifestyle recommendations specific to the outcome of interest and an individual's sociodemographic profile in conditions such as dementia and obesity.[4,7] Here, for the first time we applied compositional time-use analyses to knee OA, to explore the impact of time-use and time reallocations on knee OA symptoms. Further, we produced a web-app which displays tailored time-use recommendations for individuals with knee OA, as well as the potential effect of small time-use reallocations on knee OA symptoms.

What were the main scientific objectives of the grant?

1. To use compositional time-use analyses to model the optimal balance in daily activity distribution (i.e., time spent in different behaviours to create a "Best Day") to minimize knee OA pain intensity and interference across several sociodemographic variables.
2. To create a web-app that can be used to help communicate an individual's "Best Day" for their knee OA symptoms and to explore the potential impact of small time-use reallocations to end-users (people with knee OA and clinicians).

What were the main scientific achievements of the grant?

We evaluated the effect of daily time-use distribution on pain intensity and interference, using data from >12,000 people with knee osteoarthritis in the UK Biobank. We extracted derived accelerometry data from the UK Biobank to determine the average daily proportion of time spent in sleep, sedentary behaviour, light physical activity, and moderate-to-vigourous physical activity. We also extracted several sociodemographic and health status variables which have previously been found to be associated with knee OA pain (e.g., age, comorbidities, BMI), to allow for personalised prescriptions based on people's unique profile. We then ran multiple linear regression models to evaluate the effect of daily activity disruption on the two pain outcomes (intensity, interference). The regression models also included sociodemographic and health status variables, and second order terms (i.e., polynomial and interactions). Group LASSO regression was used to determine which variables were included in the final optimised model.

Using the output of our optimised regression model, we created time-use footprints to determine individuals "Best Day" for their knee OA, which was defined as the 5% lowest pain intensity and interference scores within the cohort. To make the footprints realistic, we added constraints, where we only considered the 80th percentile footprints. The constrained data was then used to within a web-based Shiny app, which displays the outputs from the

analysis in an interactive and accessible manner. The web-app was previously co-designed with older South Australians and clinicians to ensure it fit consumers needs.

To use the web-app, users first enter information about themselves and their health into the first page of the app (e.g., age, comorbidities, current time-use). Then, the app displays the user's "Best Day" for their knee OA, based on their own unique sociodemographic profile (Figure 1). Next, the user can click through to an interactive section, where you can explore the potential impact of small, realistic changes to daily activities on knee OA pain (Figure 2).

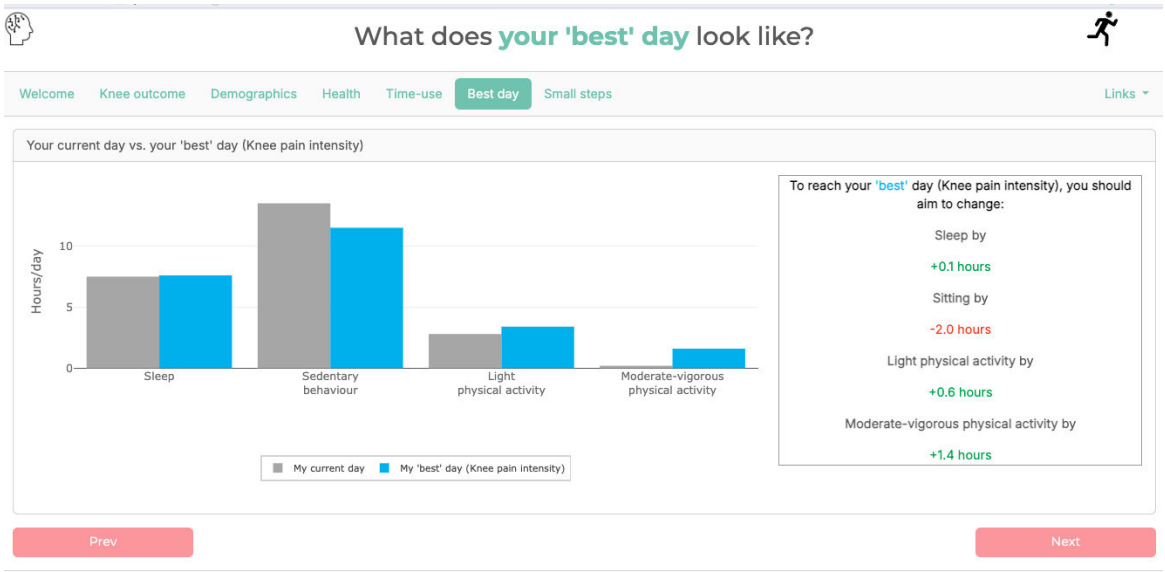

Figure 1. Best Day output for a 70-year-old female with knee OA, who is retired, has a high school education, no comorbidities, and a healthy lifestyle (i.e., does not smoke or drink). The grey bars depict this users usual activity, and the blue bars show their optimal mix in daily activities to minimize their knee OA pain intensity.

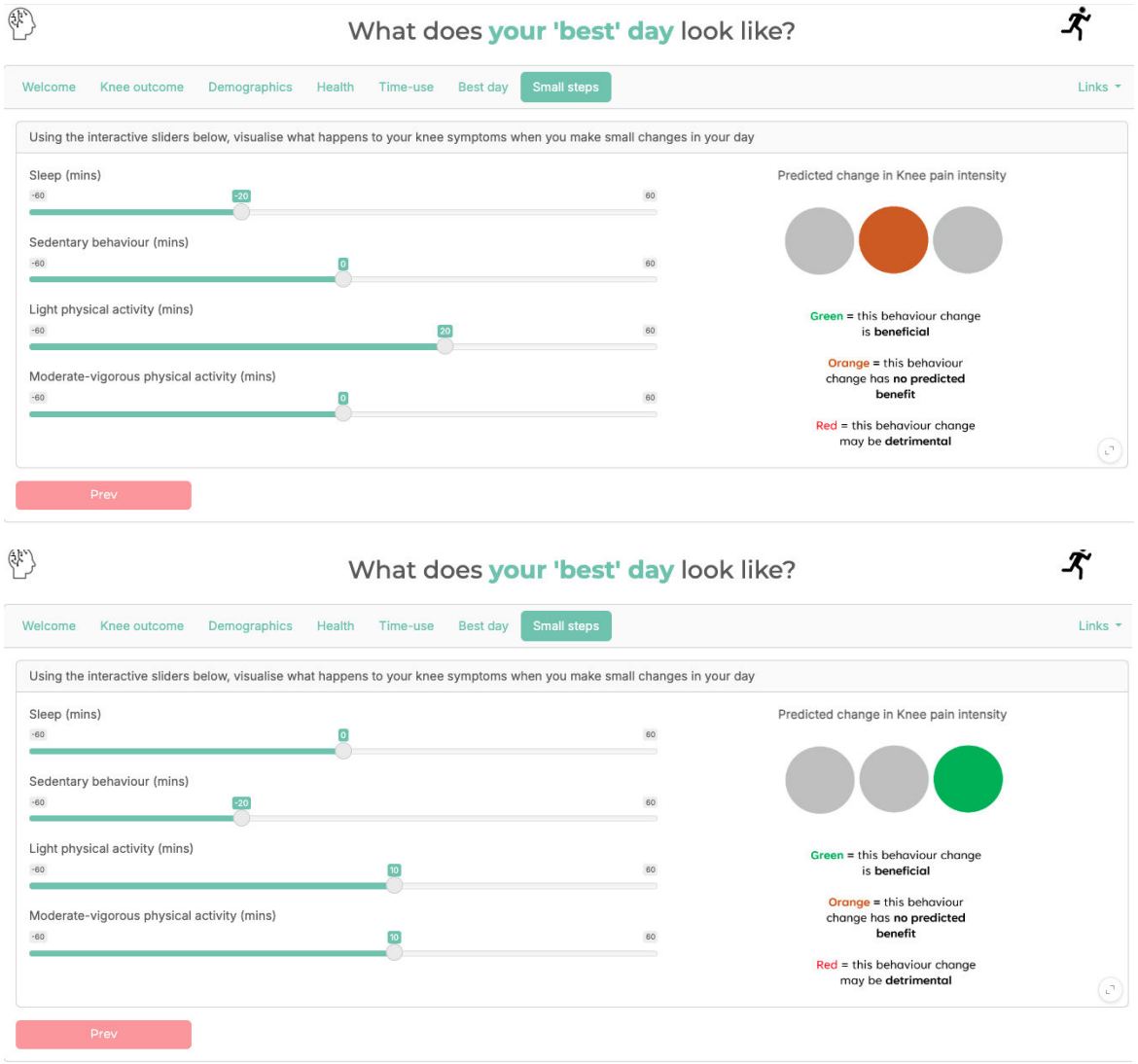

Figure 2. Interactive sliders display the potential effects of small changes in daily time-use for the same knee OA user described in Figure 1. The top panel shows that swapping 20min of sleep for light physical activity is unlikely to change knee pain intensity. The bottom panel shows that reallocating 20min of sedentary time towards a mix of light and moderate physical activity is likely to beneficial.

What problems, if any, did you encounter in achieving the project's objectives, and how did you address them?

Resource constraints precluded testing feasibility and preliminary efficacy the web-app recommendations. While were able to produce a Best Day web-app, we were unable to test its performance in real-world settings. To address this, we are currently preparing a Medical Research Future Fund grant application. If successful, this grant would fund feasibility and acceptability testing of the Best Day web-app in community physiotherapy settings.

What is the plan for dissemination of findings?

We are currently preparing a manuscript for publication detailing the development of the Best Day web-app. The findings will also be presented at an upcoming conference.

Lay summary:

Overview:

Getting the right balance of activities (sleep, sedentary time, and physical activity) throughout a day is important for our overall health and wellbeing. This is especially true for people with knee osteoarthritis. It's hard to know how much sleep, exercise, and rest to do during a day to improve your knee symptoms, as the best mix of activities is different for everyone. Adding to the difficulty is the fact that there are only 24 hours in a day, so doing more of one activity means missing out on something else. Activity trade-offs are complicated to get right and may have unintended consequences. For example, could waking up early to squeeze in more exercise at the expense of sleep inadvertently increase knee osteoarthritis pain? Or, if you already work at a physical demanding job, should you prioritise rest over more exercise when you are at home? Not knowing the answers to these questions means that it is hard for people with knee osteoarthritis to know what to do, and hard for clinicians to offer the best recommendations to their patients.

To answer these questions, we used a large dataset, which included over 12,000 people with knee osteoarthritis, to determine what balance of activities is best for each person with knee osteoarthritis, based on their unique profile (e.g., age, health status, current activity levels). We then built a web-app that allows people living with knee osteoarthritis and clinicians to view personalized recommendations for the best mix of activities to reduce knee pain. The app is interactive and allows user to explore the potential impact of small, realistic, changes in their daily activities, on knee osteoarthritis pain.

What problems did you try to solve, or gaps in knowledge did you try to fill?

People with knee osteoarthritis often describe living with osteoarthritis as a 'balancing act', and tell us that is hard to know how much activity and rest is required to live well with knee osteoarthritis. We addressed this uncertainty, by creating the "Best Day for my Knee OA" web-app. This app gives people with knee osteoarthritis guidance about the best mix of activities to manage their knee osteoarthritis. It also provides information about the potential benefits of small activity changes on knee osteoarthritis symptoms. This allows people to make small, realistic lifestyle changes to better manage their knee osteoarthritis.

What did you discover during the course of the grant?

We found that one-size-fits-all recommendations, such as "move more, sit less", may not work for everyone with knee osteoarthritis. Indeed, in some cases generic advice has the potential to worsen people's symptoms. This tells us that lifestyle recommendations should be tailored to each individual based on their unique personal profile and current mix of daily activities. Personalisation has the potential to improve non-surgical management of knee osteoarthritis, by helping more people get their daily activity balance right.

Have the findings of the research already benefited people with musculoskeletal disease? How might the findings inform further research to help sufferers in the future?

This is the first time that impact of time-use swaps has been explored in people with knee osteoarthritis. Our findings provide evidence that personalised activity recommendations may be needed to improve outcomes in people with knee osteoarthritis. Next, we want to test using our new web-app in physiotherapy clinics. We want to know if the app itself is practical to use and is seen as a good thing to add to knee osteoarthritis treatment.

Are you planning to continue the research?

Yes, we have applied for additional funding in partnership with Arthritis Australia. This funding will be used to test the feasibility, acceptability, and early effectiveness of our web-app in community physiotherapy practices.

References

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