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A Catalog of "Knee Friendly" Aerobic Exercises Developed for Patients With Knee Osteoarthritis: An International Patient Survey

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Objective. Aerobic exercise is recommended for the management of knee osteoarthritis (OA), but knee pain is often a barrier for participation. Some types of aerobic exercise may be less painful to undertake than others, though little is known about which are the most "knee friendly," that is, unlikely to exacerbate knee pain to an unacceptable level. This study aimed to identify aerobic exercise activities that (1) are knee friendly and (2) meet requirements for targeting cardiovascular health.

Methods. We conducted a three-phase international survey. In phase 1, persons living with knee OA provided descriptions of knee friendly exercise types, defined as activities that would cause shortness of breath and difficulty talking without worsening symptoms to an unacceptable level (cause severe symptoms and/or lasting more than 24 hours). In phase 2, exercise physiologists identified exercise activities meeting requirements for increasing aerobic fitness, which were grouped into broader aerobic exercise activities. In phase 3, participants nominated each aerobic exercise activity for "knee friendliness."

Results. In phase 1, 487 respondents (Denmark: 259; the Netherlands: 144; Australia: 57; and North America: 15) provided a total of 1,590 exercise descriptions. In phase 2, 154 exercise activities were identified and grouped into a list of 30 broader aerobic exercise activities. In phase 3, 349 participants (Denmark: 195; the Netherlands: 114; Australia: 32; and North America: 8) nominated indoor biking and water exercise as most knee friendly (82% and 70%, respectively). Participants were predominantly women (60.7%), the mean ± SD age was 68.4 ± 8.81 years, the mean ± SD body mass index was 27.5 ± 5.8, the mean ± SD self-efficacy score was 7.3 ± 3.0 (0–10 scale), the mean ± SD symptom duration was 11.7 ± 9.05 years, and the mean ± SD current knee pain was 4.5 ± 2.2 (0–10 scale).

Conclusion. A catalog of 30 knee friendly aerobic exercise activities was generated for individuals living with knee OA. The catalog aims to empower individuals living with knee OA, offering suitable aerobic exercise options without exacerbating knee pain.

INTRODUCTION

Knee osteoarthritis (OA) is the most common reason for knee pain in adults and is associated with increasing prevalence of comorbidities (such as obesity), physical inactivity,[1] and increased risk for cardiovascular disease and death.[2,3] Exercise therapy is a cornerstone in clinical care to reduce knee OA–related pain.[4–6] The current exercise recommendation for adults

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SIGNIFICANCE & INNOVATIONS

- Aerobic exercise is recommended for the management of knee osteoarthritis (OA), but knee pain is often a barrier for participation. However, not all persons are limited equally by the same types of aerobic exercise, and little is known about which are the most "knee friendly," that is, unlikely to provoke knee pain.
- In this international three-phase patient-centered survey, individuals living with knee OA provided descriptions of exercise types they could do at high intensity without worsening of knee OA symptoms and nominated each exercise activity for perceived "knee friendliness."
- A catalog of 30 knee friendly aerobic exercise activities were generated by and for individuals living with knee OA. The catalog will hopefully enable and inspire individuals living with knee OA to perform aerobic exercise activities that are relevant and suitable for their individual circumstances without exacerbating knee pain.

with chronic diseases and disabilities is 150 min/wk of moderate- to vigorous-intensity aerobic exercise.[7] The rationale for recommending aerobic exercise for individuals with knee OA is primarily its known reductions in knee OA–related pain, disability,[4–6] and depression and the further reduced risk of cardiovascular disease and events.[8–10] Furthermore, aerobic exercise at high intensities (heart rate at or above 80%–95% of maximum)[11] provides more robust cardiovascular health benefits compared to aerobic exercise at moderate intensity.[10] Nevertheless, many individuals living with knee OA are less engaged in aerobic exercise and physical activity than healthy individuals, which is most likely due to knee OA symptoms.

Recommending specific aerobic exercises is challenging because individuals with knee OA exhibit diverse limitations to a large variety of aerobic exercises, suggesting a need for a tailored approach.[9] It therefore seems important to identify aerobic exercise activities that are likely to be "knee friendly" from the perspectives of many patients and have the potential to improve both knee symptoms and cardiorespiratory fitness. Within this context, "knee friendliness" is defined as exercise activities that do not exacerbate knee OA–related pain (with symptoms being severe and/or lasting for more than 24 hours). A catalog of knee friendly aerobic exercise activities will enable individuals with knee OA to choose aerobic exercise activities that are of interest, relevant, and suitable for their specific circumstances and preferences, with low likelihood of exacerbating the painful knee. The aim of this study was to identify aerobic exercise activities that (1) are knee friendly and (2) are believed to elicit an improvement in cardiorespiratory fitness.

PATIENTS AND METHODS

The study used a sequential survey design and was conducted in Australia, Denmark, North America (Canada and United States), and the Netherlands. The survey was translated into each country's spoken languages by participating researchers. There was no patient involvement in the design of the study or surveys or in the interpretation of the data. The recruitment process was conducted via existing networks of patients, including clinical databases (previous study participants in the various participating countries), Facebook advertisements (targeted the relevant population in Australia), newsletters (for patient with OA in the Netherlands), and webpage promotions via patient organizations (such as Arthritis Society Canada). The recruitment resources in the individual countries were identified by the participating investigators, who provided public links to the survey, including the plain language statement. The surveys were managed using the web-based survey service REDCAP,[12] hosted in the Capital Region of Denmark. Each participating country had a dedicated survey link (Canada and United States used the same). A pilot test and refinement of the questionnaires in phases 1 and 3 occurred among the investigators before the survey was distributed. The pilot test aimed to ensure the questions in phases 1 and 2 were relevant to their specific aims and needs and were reviewed and tested for functionality, wording, and user friendliness. The study is reported according to Consensus-Based Checklist for Reporting of Survey Studies guidelines.[13] The survey consisted of three phases (Figure 1).

Phase 1. *Self-screening.* Eligibility was determined from initial survey questions. Adult patients were eligible if they had been diagnosed with knee OA by a medical doctor or met the National Institute for Health and Care Excellence (NICE) criteria[4] for self-reported knee OA: age ≥45 years, knee pain with activity (eg, walking, standing, exercising), and either no morning knee joint stiffness or morning knee joint stiffness lasting ≤30 minutes. Eligible respondents were asked to provide informed consent to participate.

Description of exercise activities. Participants were asked to provide a name and a description of knee friendly exercise activities. In this study, knee friendly exercise activities were defined as activities participants either could do or could imagine themselves doing for exercise purposes and that would make them short of breath and make it difficult for them to talk (only short sentences and one- or two-word answers were possible). The activity should also not worsen knee symptoms to an unacceptable level,

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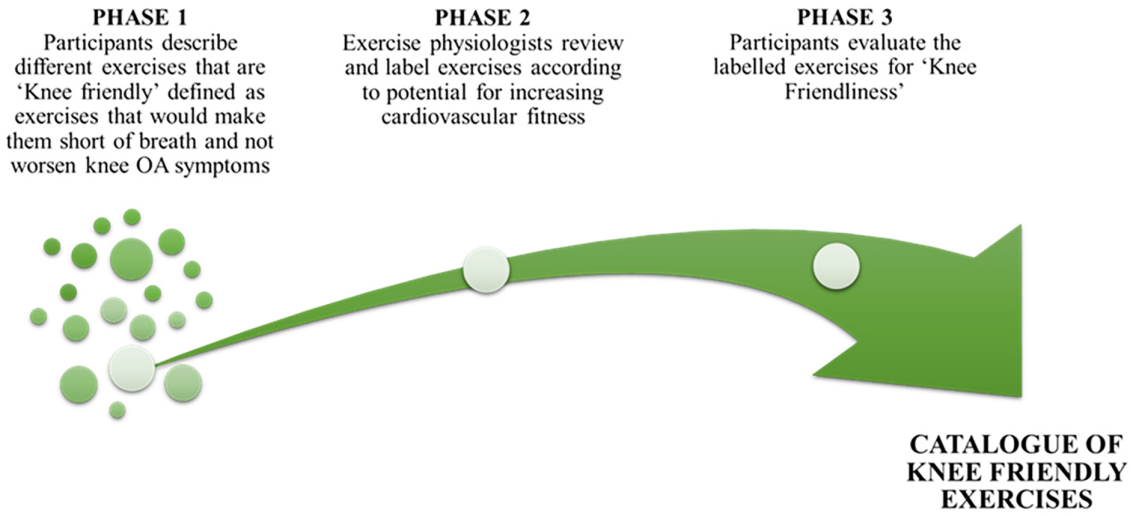

Figure 1. Design and development of the survey using a sequential method consisting of three phases. OA, osteoarthritis.

defined as symptoms that are severe and/or last for more than 24 hours. The survey highlighted that exercise with some knee pain (mild to moderate) was acceptable and safe and emphasized that there were no restrictions on the types of activities the participants could provide and that they did not have to be "conventional" exercises. Examples of activities were provided for inspiration (walking, rowing outdoors, cycling, swimming, hiking, and more). For practical reasons, the maximum number of exercise activities a participant could provide was 50.

The phase 1 survey also collected sociodemographic data, including sex assigned at birth (female or male), living arrangements (living alone or living with someone), age, height, body weight, education level, occupational status, comorbidities, and smoking status. Participants were asked to provide information about self-rated physical fitness (5-point Likert from 0 [poor] to 4 [very good]), and self-rated exercise efficacy (confidence in unspecified exercise three times per week for at least 30 minutes) on a 0 to 10 scale (0 = not confident; 10 = very confident). Finally, we asked for knee OA symptom duration (years), current knee pain on a numeric pain rating scale (0 = no pain; 10 = worst possible pain), and the Knee Injury and Osteoarthritis Outcome Score short form (KOOS-12) score using the pain, symptoms, and knee-related quality of life subscales.[14] Additionally, participants were requested to consent to further participation by providing an email address for the subsequent phase of the study (phase 3), to which an invitation link would be sent.

Phase 2: Review and labeling of exercise activities. Exercise activities from phase 1 were reviewed by three exercise physiologists (TB, MR-L, and MP) each possessing expertise in exercise physiology. The activities were assigned an activity label and a metabolic equivalent task (MET) value using the Compendium of Physical Activities.[15] MP systematically classified the activities, providing each with a specific label (eg, swimming, ball games, cycling) and an associated MET value. All three exercise physiologists collaborated on the condensation of activities into a concise list. Subsequently, activities capable of increasing heart rate and inducing shortness of breath, corresponding to an MET value of at least 6, were selectively chosen. An example of this process appears as follows: activity name, walking; activity description, walking at moderate or fast pace (9–10 min/km); activity label, brisk walking; activity MET value, 6.

All exercise activities were then further categorized and pooled into broader exercise activities with brief descriptions. The activities were sorted into two categories: (1) "aerobic exercises," which consisted of activities that were considered to meet the requirements for increasing cardiorespiratory fitness (MET value ≥6) if performed as regular exercise training (repeated bouts of exercise) for an extended period of time (eg three months), and (2) "other types of exercise," which consisted of activities that did not meet these requirements (ie, MET value <6).[15] The rationale behind categorizing the activities into two groups lies in the intention to emphasize high-intensity activities (MET value >6) within the catalog, thereby focusing on the activities that can target cardiovascular risk factors.[10,16,17]

Phase 3: Nomination of knee friendliness. The list of the broader aerobic exercise activities generated in phase 2 was returned to consenting participants from phase 1. Participants were asked to review the list of aerobic exercises with the question "Which types of exercise do you find knee friendly?" Knee friendliness was reiterated as activities that would not worsen their knee symptoms to an unacceptable level (defined as symptoms that are severe and/or last for more than 24 hours). The safety of doing exercise with some symptoms (mild to moderate) was also repeated. Furthermore, the participants were reminded that the activities should be done at an intensity that would make them short of breath and make it difficult for them to speak in more than

short sentences and one- or two-word answers. It was emphasized that the participants should not consider whether they found the exercise type interesting, had the opportunity to perform it, or had access to required facilities or equipment, nor was it a prerequisite that the respondents had current or past experiences with the exercise types. The nomination of knee friendliness was dichotomous (knee friendly or not).

Next, participants were asked to assess which of their selected knee friendly exercises they could imagine doing for at least 45 minutes two to three times a week as part of a regular exercise routine. Adhering to this frequency and duration aligns with established guidelines for promoting cardiorespiratory health.[17–19] Participants were informed to keep in mind that the exercise should be performed at a high intensity (high heart rate causing sweating and shortness of breath) and that access to the specific training facilities should not be a consideration.

Study data management. The survey was conducted according to the guidelines of the Danish Data Protection Act and followed the European Union General Data Protection

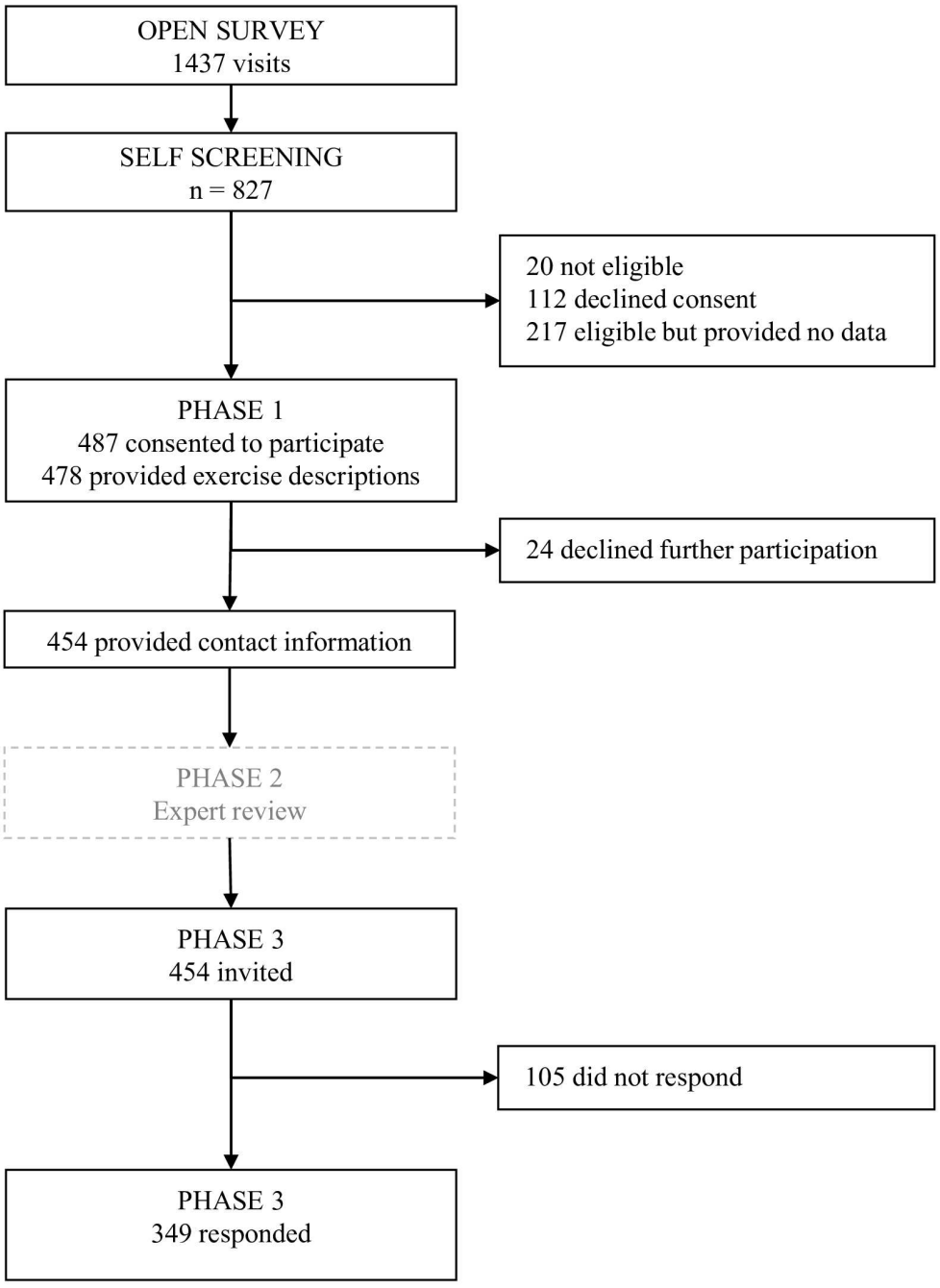

Figure 2. Flow of study participants.

Table 1. Characteristics of the study participants in phases 1 and 3*

Characteristics	Phase 1 (n = 487)	Phase 3 (n = 349)	Not participating in phase 3 (n = 129[a])	Difference from phase 3 participants, SMD
Female sex, n (%)	290 (60.7)	224 (65.5)	120 (63)	0.04
Age, mean ± SD, y	68.4 ± 8.81	68. 6 ± 8.7	67.9 ± 9.1	0.08
Body mass index, mean ± SD	27.5 ± 5.8	27.1 ± 5.8	28.6 ± 6.6	−0.25
Living alone, n (%)	156 (34.7)	114 (32.7)	43 (31.2)	0.06
Education, n (%)				
Primary school	14 (2.9)	6 (1.7)	8 (6.2)	−0.23
Secondary school	57 (11.9)	38 (10.9)	20 (14.5)	−0.14
Trade or trade certificate	83 (17.4)	67 (19.2)	19 (13.8)	0.12
University or tertiary institute	153 (32.0)	111 (31.8)	44 (31.9)	−0.05
Higher university degree	118 (17.3)	100 (28.7)	20 (14.5)	0.32
Don't know/unsure	28 (5.9)	20 (5.7)	9 (6.5)	−0.05
Employment, n (%)				
Working	139 (29.1)	105 (30.1)	36 (30.5)	0.05
Not working	29 (6.1)	21 (6.0)	9 (6.5)	−0.04
Retired	285 (59.6)	218 (62.5)	73 (52.9)	0.12
Work including knee loading, n (%)	175 (36.6)	122 (35.0)	56 (40.6)	−0.23
Comorbidities, n (%)				
Heart disease	56 (11.7)	48 (13.8)	9 (6.5)	0.22
Hypertension	126 (26.4)	95 (27.2)	34 (24.6)	0.02
Diabetes	35 (7.3)	19 (5.4)	16 (11.6)	−0.25
Depression or anxiety	28 (5.9)	12 (3.4)	17 (12.3)	−0.36
Low back pain	145 (30.3)	105 (30.1)	42 (30.4)	−0.05
Hip pain	95 (19.9)	69 (19.8)	28 (20.3)	−0.05
Foot pain	129 (27.0)	84 (24.1)	48 (34.8)	−0.29
None of the above	104 (21.8)	84 (24.1)	48 (34.8)	−0.29
Smoking status, n (%)				
Never	150 (45.2)	161 (46.1)	51 (37.0)	0.13
Former	162 (48.8)	167 (47.9)	60 (43.5)	0.03
Current	10 (3.0)	11 (3.2)	6 (4.3)	−0.08
Current physical activity routine, n (%)				
Never	3 (0.6)	2 (0.6)	1 (0.7)	−0.02
Rarely (1–2 times/month)	21 (4.4)	12 (3.4)	9 (6.5)	−0.16
Sometimes (once/week)	51 (10.7)	38 (10.9)	16 (11.6)	−0.05
Often (2–3 times/week)	214 (44.8)	162 (46.4)	55 (39.9)	0.08
Every day	162 (33.9)	126 (36.1)	39 (28.3)	0.12
Self-rated fitness, n (%)				
Very good	42 (8.8)	28 (8.0)	15 (10.9)	−0.12
Good	86 (18.0)	60 (17.2)	27 (19.6)	−0.10
Moderate	174 (36.4)	126 (36.1)	51 (37,0)	−0.07
Fair	124 (25.9)	110 (31.5)	17 (12.3)	0.45
Poor	27 (5.6)	19 (5.4)	9 (6.5)	−0.06
Exercise self-efficacy (0–10[b]), mean ± SD	7.3 ± 3.0	7.5 ± 3.0	6.5 ± 3.1	0.36
Symptom duration, mean ± SD, y	11.7 ± 9.05	11.8 ± 9.1	10.9 ± 8.5	0.10
Current knee pain (0–10[c]), mean ± SD	4.5 ± 2.2	4.6 ± 2.2	4.9 ± 2.2	−0.15
KOOS-12 (0–100[d]), mean ± SD				
Pain	47.4 ± 20.7	46.9 ± 20.5	48.3 ± 21.3	−0.07
Function	60.6 ± 18.9	61.0 ± 18.9	59.5 ± 19.2	−0.08
QoL	44.4 ± 17.3	44.6 ± 17.0	43.0 ± 18.5	−0.08

*KOOS, Knee Injury and Osteoarthritis Outcome Score; QoL, quality of life; SMD, standardized mean difference.
[a]Data on characteristics missing from 9 participants.
[b]0–10 scale (0 = not at all confident; 10 = highly confident).
[c]0–10 scale (0 = no pain; 10 = worst imaginable pain).
[d]0–100 scale (0 = extreme knee problems; 100 = no knee problems).

Regulation. As part of the self-screening (phase 1), all participants gave informed consent. Participants who took part in the final phase of the study were asked to provide an email address so that the phase 3 survey could be sent to them. Study data management and data security procedures were approved by the Danish Data Protection agency before study commencement.

Statistical analysis. The sociodemographic and knee OA–related data are presented as means with SDs. Dichotomous and categorical data are presented as numbers and percentages. We compared participants who completed phase 3 with those who did not by means of standardized mean differences (SMDs). Exercise activities nominated as knee friendly are

reported as numbers and percentages. To assess the association between sociodemographic or knee OA–related variables and the perceived knee friendliness of each exercise, we conducted univariate logistic regression analyses with knee friendliness (yes or no) as the dependent variable and the sociodemographic and knee OA–related factors as independent variables. Results are reported as odds ratios with 95% confidence intervals. No adjustments for multiplicity were applied because these analyses are considered exploratory, and no firm conclusions will be made. Statistical significance was set to the 0.05 level (two-sided). Statistical analyses were performed using IBM SPSS Statistics 28.0.

RESULTS

Participant flow and characteristics. The surveys sampled data from October 5, 2022, to May 23, 2023. The landing page of the phase 1 survey received a total of 1,437 visits, with a breakdown by region as follows: Denmark, 851 visits; the Netherlands, 353 visits; Australia, 190 visits; and North America, 43 visits. Among the visitors, 487 respondents (Denmark: 259; the Netherlands: 144; Australia: 57; and North America: 15) provided exercise descriptions. Subsequently, in phase 3, a total of 349 participants engaged in the survey, with participation distributed across regions: Denmark, n = 195; the Netherlands, n = 114; Australia, n = 32; and North America, n = 8. The participant flow is illustrated in Figure 2.

Participants were predominantly female (60.7%; n = 290), with a mean age of 68.4 (SD 8.8) years, a mean body mass index (BMI) of 27.5 (SD 5.8), and a high exercise self-efficacy score (mean 7.3, SD 3.0) on a 0–10 scale (Table 1). The mean symptom duration was 11.7 (SD 9.05) years. The participants in phase 3 were largely comparable, as judged by the SMDs (Table 1), to those who did not continue participation in phase 3. The characteristics of the participants in phases 1 and 3 are shown in Table 1.

Phases 1 and 2. The 487 participants provided in total 1,590 exercise activities (Supplementary Table 1). After removal of duplicates, 154 unique exercise activities were identified and included in phase 2. These 154 unique exercise activities were pooled into broader categories that were labeled, briefly described, and associated with an MET value. This resulted in 30 aerobic exercise activities (Table 2) that were included in phase 3.

Phase 3. The 349 participants indicated which of the 30 activities they perceived to be knee friendly (yes or no). The aerobic exercise activities that received the most knee friendliness votes were indoor biking (285 votes; 82%) and water exercise class (246 votes; 70%). Three hundred thirteen (90%) participants chose at least one activity from the top five knee friendly aerobic exercise activities. The exercise activities with fewest votes were skiing (15 votes; 4%) and karate (6 votes; 2%). The knee friendliness ratings for each of the aerobic exercise activities are illustrated in Figure 3. The percentage of knee friendliness ratings from each participating country is illustrated in Supplementary Figure 1. The results are fairly comparable, although stair training stood out as the sole activity within the top 10 list in Denmark.

The aerobic exercise activities that the participants could imagine themselves doing two to three times per week for 45 minutes as part of a regular routine are shown in Figure 4. Indoor biking (156 votes; 45%), outdoor biking (143 votes; 41%), brisk walking (143 votes; 41%), and water exercise class (139 votes; 40%) received the most votes. Two hundred eighty-six (82%) participants could imagine themselves doing at least one activity from the top five of the list.

Associations between sociodemographic characteristics and knee OA–related data and knee friendliness for each exercise activity are shown in Supplementary Table 2. In general, there were few statistically significant associations suggesting that better self-reported knee OA status increases the odds of finding an exercise activity as knee friendly. The statistically significant associations were typically weak (odds ratios <2.00), and there was no clear pattern regarding participant characteristics or knee OA–related data. Associations between the individual items of the KOOS-12 questionnaire (12 questions focusing on knee problems in relation to the three subscales for pain, function, and quality of life) and knee friendliness ratings of each exercise activity are shown in Supplementary Table 3. In summary, there were some indications that participants with less impairments regarding knee OA–related pain, function, and quality of life were more likely to nominate hiking, spinning, and using the cross trainer as knee friendly; however, the associations were weak (odds ratios <2.00) and not systematic.

DISCUSSION

To help increase uptake and engagement with exercise, we developed a catalog of knee friendly aerobic exercises using a three-phase sequential survey. This exercise catalog is a novel effort resulting from substantial input from individuals living with knee OA.

Indoor biking and water exercise classes were most frequently nominated as knee friendly. Moreover, these were at the top of the list of aerobic exercises that the participants could imagine themselves doing two to three times per week for 45 minutes as part of a regular routine. The beneficial effects of stationary cycling exercise compared to no exercise control on knee OA pain have been documented in a systematic review and meta-analysis[20] from 2020. Also, supervised group cycling on stationary bicycles and aquatic exercise are among the most common aerobic exercises included in the studies underlying the

Table 2. List of aerobic exercise activities with an intensity of ≥6 METs, ordered alphabetically*

Exercise activity name	Description
Agility training	A ladder-shaped training tool is used and placed on the ground, after which you can perform a number of different stepping exercises at a high pace.
Boxing	Performed in a gym/club, with gloves and sandbags used. Training is based on boxing techniques and sparring between participants at high intensity.
Brisk walking	Can be done indoors and outdoors with a focus on high speed that causes shortness of breath.
Circuit training	Involves selected exercises (either on a machine or with free weights or body weight) arranged in a circuit. Training takes place at a high pace with short breaks.
Class training in fitness clubs	An instructor guides a series of exercises (functional exercises, weight training, etc) composed specifically for the class theme. The focus is on a high pace.
Cross trainer	A fitness machine that uses the whole body. The muscles in both the lower and upper body work simultaneously at a high pace.
CrossFit	A mixture of gymnastics, weightlifting, and sprinting, combined in a series of exercises performed at a high pace within a given period of time.
Dance	Different dance styles such as Argentinian tango, line dance, disco dance, standard dance, folk dance, cha-cha-cha, rumba, rhythmic dance, Zumba.
Gymnastics	Bodily exercises that focus on strength, explosiveness, and flexibility as well as the two styles of rhythmic and artistic gymnastics. Can be done in clubs/associations, in gyms, or at home.
High-intensity ball games	Such as soccer, tennis, badminton, basketball, rugby, and pickleball. The exercise is characterized by acceleration/running in intervals and few breaks and can be played in larger teams or as doubles or singles.
Hiking	Walking over longer distances and can be done in different terrains (mountains, beach, city, etc).
Indoor biking	Biking on a stationary bike/exercise bike in the gym or at home.
Indoor rowing	Indoor rowing can be done on a machine in a gym or at home.
Interval walking	Walking at alternating speeds from fast to slow. When walking fast, you must walk at a pace that makes you clearly short of breath.
Karate	A martial art that combines both physical fitness and expression. The training mainly consists of punches, kicks, and blocks at high speed.
Kayak	A kayak is propelled forward with a paddle using arm power. Kayaking can be done on the sea by one or more people.
Outdoor biking	Biking outdoors can be cycling as transportation, road racing, mountain biking, and/or cycling in hilly terrain.
Paddleboarding	Paddleboarding is a water sport in which you have positioned yourself in the middle of a large surfboard on the water, which is propelled forward by means of a paddle. Paddleboarding can be done standing or sitting.
Pole walking (Nordic walking)	Pole walking is walking that is supplemented with two poles as an aid. The poles provide an increased training effect because the arms and upper body are activated during the walk. The poles also increase balance during training.
Rowing indoors	Indoor rowing can be done on a machine in a gym or at home.
Rowing outdoors	Rowing outdoors can be done by one or more people on the sea or a lake. Rowing can cause shortness of breath.
Running indoors	Running indoors can be done on a treadmill.
Running outdoors	Running outdoors can be done in the city, in parks/forests, and in the countryside.
Skiing	Skiing includes cross-country skiing, alpine skiing, and snowboarding.
Skipping	Skipping takes place by jumping or running while a skipping rope is swung with the arms.
Spinning	Spinning is indoor cycling in a class on stationary exercise bikes in a fitness club. The class is managed by an instructor who has planned a program and is often characterized by high tempo intervals.
Stair training	Stair training involves training on stairs outdoors or indoors, for example, in stairwells.
Step machine	Step machine exercises are performed on a step machine similar to climbing stairs, and the purpose is to activate the large muscles in the legs.
Surfing	Surfing takes place by standing on a surfboard on the sea with the waves as a driving force. Surfing also involves swimming.
Swimming	Course swimming that involves different styles, such as breaststroke, crawl, back crawl, butterfly, etc.
Water exercise class	Water exercise (also known as "Aqua fit" or "water aerobics") is exercises in the water that requires fitness, coordination, and strength.

*MET, metabolic equivalent task.

American College of Rheumatology's (ACR) recommendation of exercise as treatment of knee OA.[6]

Pole walking, brisk walking, and interval walking activities with high intensities were also frequently nominated as being knee friendly and at the top of the list of aerobic exercises that the participants could imagine doing regularly. Altogether, this is in accordance with the ACR guideline that recommends walking for the management of OA.[6] Recently, Lo et al[21] found walking for exercise was associated with less frequent development of knee pain and suggested walking for exercise could potentially be disease modifying. Altogether, this supports the use of walking to both improve knee OA symptoms and elicit an improvement in cardiorespiratory fitness.[22,23]

Besides being effective in reducing cardinal knee symptoms, aerobic exercise also improves cardiovascular health.[11,24] Although each of these knee friendly exercise activities can

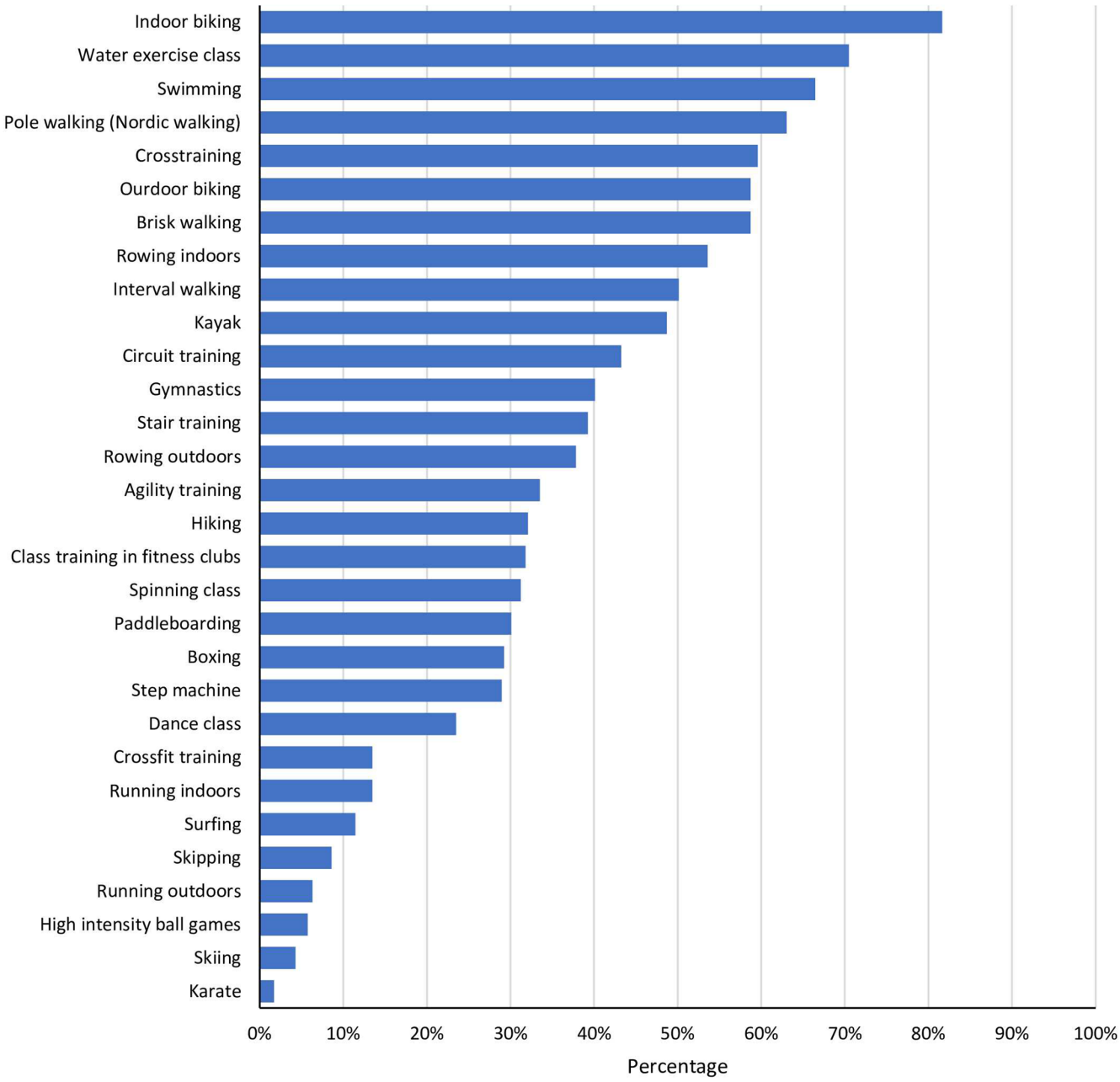

Figure 3. Percentages of phase 3 participants nominating each aerobic exercise type as "knee friendly." The total number of participants was 349.

enhance cardiovascular health, comparative differences in efficacy remain minimal when intensity, frequency, and duration are consistent.[25] The Ottawa Panel's recommendations for enhancing cardiorespiratory fitness in patients with knee OA using aerobic walking endorse a minimum exercise duration of 30 minutes performed at an intensity exceeding normal daily activities with a suggested frequency of at least three to four sessions per week.[26] However, aerobic exercise is often underused in management of knee OA.[27] Holden et al[27] conducted a cross-sectional survey investigating physical therapists' use of therapeutic exercise in patients with knee OA and found that 99% of all physical therapists indicated a preference for employing therapeutic exercise in the treatment of this patient group, with a focus on strengthening exercise rather than aerobic exercise. From a clinician's perspective, strengthening exercises aim to alleviate symptoms that may limit participation in aerobic activities, and with improved symptoms, aerobic exercise activities may be possible. The present catalog can inspire patients to engage in aerobic exercise.

Despite recognizing the benefits of exercise, patients with knee OA often face various challenges in adopting and adhering to exercise regimens. Common barriers include pain exacerbation

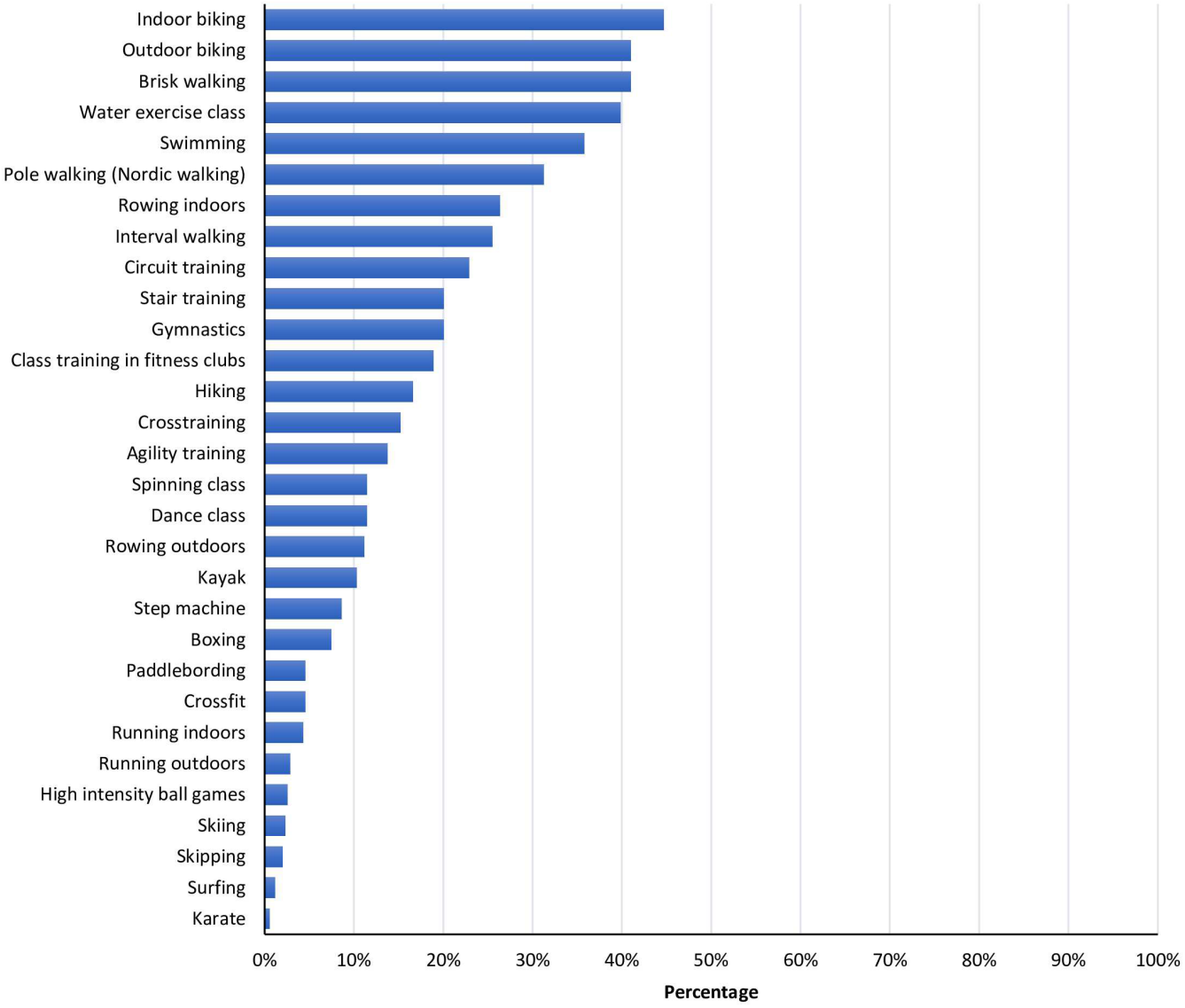

Figure 4. Percentages of participants in phase 3 who would consider doing the aerobic exercise activities two to three times per week for 45 minutes each time at high intensity (high heart rate, causing sweating and shortness of breath). The total number of participants was 349.

during physical activity, fear of injury, lack of motivation, and difficulty incorporating exercise into daily routines.[26] Additionally, comorbidities such as cardiovascular disease and obesity may further complicate exercise participation.[28] The barriers and perception of exercise effectiveness vary among individuals with knee OA. Factors such as age, sex, socioeconomic status, and previous experiences with exercise influence patients' attitudes and behaviors toward physical activity.[29] Personalized exercise guidance is likely to promote uptake.

Developing a catalog of aerobic exercises tailored for individuals with knee OA addresses barriers to exercise adherence. By involving patients in identifying knee friendly exercises, the catalog reflects the diverse needs of this group, increasing its relevance and acceptability. We are disseminating the catalog through various platforms, including patient organizations and rehabilitation centers. The catalog aims to inspire patients to find suitable exercise options that fit their needs and preferences, supporting behavior changes and integration into other management strategies.

Surfing, skiing, karate, and high-intensity ballgames received relatively low numbers of knee friendliness votes, which is not surprising because these types of exercises are associated with high knee joint load and require a high level of skills and functioning and rapid whole-body movement with a preplanned change of velocity and speed. It seems reasonable that these exercises were ranked lowest because of knee OA–associated reduced strength, stability, and functioning.[30] However, it is an interesting finding that these activities were suggested as knee friendly in the first phase. It seems reasonable that skiing and surfing might be explained by country-specific differences and availabilities, for

example, skiing and surfing may be more prevalent in Canada and Australia, respectively, than in Europe. Nevertheless, for some individuals living with knee OA, such activities are seemingly considered knee friendly, perhaps also weighing in other aspects of the activities, such as socioeconomic factors and quality of life, as important for individuals living with knee OA.

Overall, there were few statistically significant associations between sociodemographic characteristics and knee OA–related data and the knee friendliness ratings. These associations were randomly distributed but generally indicated that individuals with better self-reported knee OA status were inclined to perceive several types of exercise activities as knee friendly. A plausible interpretation is that individuals with less severe knee OA may find a broader range of aerobic exercise activities suitable for their condition. It is important to note that we did not collect objective data such as radiographic disease severity or alignment, which could impact knee friendliness ratings and potentially could interact with the effectiveness or safety of some activities.

The catalog of knee friendly exercises consists of a wide range of aerobic exercises that are suggested by individuals living with knee OA to others with the condition, and this is the great strength and a unique feature of this study.[27] The international contribution is also a significant strength. Furthermore, most of the aerobic exercises can be performed both supervised and unsupervised. The variety in activities may motivate patients and guide discussions with clinicians about starting or maintaining an aerobic exercise routine.

There are also limitations to our study. First, the use of existing patient networks and clinical databases introduces a potential for sampling bias, wherein individuals connected to these networks may not fully represent the broader knee OA population, potentially leading to results that are not fully generalizable. Furthermore, the recruitment method involving patient organizations and clinical databases might attract individuals already actively engaged in managing their condition, potentially leading to an overrepresentation of those with a heightened interest in exercise, thus impacting the study's outcomes. Dependence on platforms such as Facebook and web-based promotions in recruitment methods may introduce a digital device bias, particularly affecting older populations or those with lower socioeconomic status who may not have equal access to or be comfortable with using these online platforms. The regional representation was not balanced, with Europe having greater representation (83%) and only a few respondents from North America (3%). This may have biased activity nomination and selection, as cultural differences in common activities (eg, cycling) likely exist. Furthermore, we acknowledge that the study relies solely on self-reported data, including self-reported knee OA diagnosis, which introduces a potential for misclassification. The study population appears to be more physically active than the general knee OA population,[31] which may limit the generalizability to the entire knee OA population. Also, self-reported physical activity and BMI may be overreported or underreported, as evident in other studies in discrepancies between self-reported physical activity and objectively measured physical activity.[32]

It is important to acknowledge that the study did not provide clarification of the interpretation of "mild," "moderate," and "severe." The lack of standardization may introduce variability in responses and consequently affect the interpretation of the findings. However, it is crucial to emphasize that pain is a subjective experience influenced by multiple factors, including individual perception, contextual factors, and psychological aspects.[33]

Importantly, this study focused on aerobic exercise activities, and there are many other types of exercise and physical activities that are not included but may still be considered knee friendly. A similar approach could be used for generating catalogs of knee friendly exercises with aims other than cardiorespiratory fitness. Moreover, the generated catalog encompasses a mix of specific exercises (eg, indoor biking) and general exercise concepts (eg, agility training). This may cause some confusion for people looking for specific guidance but will hopefully still provide the intended inspiration.

Finally, not all aerobic exercises in the catalog have been validated among patients with knee OA for their efficacy in alleviating knee pain, improving cardiorespiratory fitness, or reducing cardiovascular risk. Although activities such as walking, biking, and water exercises have shown some evidence of alleviating knee OA pain,[34–37] the catalog primarily serves to recommend exercises that are likely to be tolerated rather than those that are proven effective. This represents a limitation, highlighting the need for validation studies to establish the effectiveness of the catalog exercises. On the other hand, no one exercise type has been proven to be more efficacious on knee symptoms than other types.[38,39] Therefore, the feasibility and effectiveness of most of the catalog exercises remain uncertain until validation studies are conducted. Although the survey aimed to identify knee friendly exercises based on minimizing knee discomfort, it may have overlooked individual preferences and feasibility. Although less than half of the respondents would consider performing the individual top five exercises two to three times per week for 45 minutes at high intensity (Figure 4), 82% of participants could imagine themselves doing at least one activity from the top five. The differences between the percentages of respondents finding various exercise types knee friendly and the percentages stating they would perform the exercises regularly are substantial, indicating that activity avoidance may be prevalent in this population and highlighting the importance of patient education and support to encourage engagement in suitable physical activity. This may limit practical applicability of the individual exercises but underscores the inspirational aspect of the catalog as a whole. However, the activities were described with MET values adequate to induce cardiovascular effects if performed consistently over 8 to 12 weeks. Additionally, it has not been possible to differentiate between types of exercise regarding their efficacy on knee OA symptoms,[38,39]

indicating that symptomatic benefit may be independent of exercise type. We recommend that different aerobic exercise activities be investigated for benefit on both knee OA symptoms and cardiovascular health. We also recommend identifying if certain patient subgroups respond differently to various exercise types.

In conclusion, we present a catalog of knee friendly aerobic exercise activities based on data input from individuals living with knee OA. The exercises have been evaluated by exercise physiologists for potential to improve cardiorespiratory fitness if performed on a regular basis and nominated as knee friendly by individuals living with knee OA. The catalog can serve as a source of inspiration for individuals with knee OA who want to exercise but need help finding activities that do not worsen their knee pain. The catalog will hopefully enable and inspire individuals living with knee OA to perform aerobic exercise activities that are relevant and suitable for their individual circumstances without exacerbating knee pain.

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AUTHOR CONTRIBUTIONS

All authors contributed to at least one of the following manuscript preparation roles: conceptualization AND/OR methodology, software, investigation, formal analysis, data curation, visualization, and validation AND drafting or reviewing/editing the final draft. As corresponding author, Dr Henriksen confirms that all authors have provided the final approval of the version to be published and takes responsibility for the affirmations regarding article submission (eg, not under consideration by another journal), the integrity of the data presented, and the statements regarding compliance with institutional review board/Declaration of Helsinki requirements.

ROLE OF THE STUDY SPONSOR

Sygeforsikring "danmark" (Sundhedsdonationer) and TrygFonden had no role in the study design or in the collection, analysis, or interpretation of the data, the writing of the manuscript, or the decision to submit the manuscript for publication. Publication of this article was not contingent upon approval by Sygeforsikring "danmark" and TrygFonden.

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