How is sport participation related to mortality, diabetes and prediabetes for different body mass index levels?

Willem de Boer1,2 | Eva Corpeleijn3 | Louise Dekker4,5 | Jochen Mierau5 | Ruud Koning1

1Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands
2School of Sport and Exercise Studies, HAN University of Applied Sciences, Nijmegen, The Netherlands
3Department of Epidemiology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
4Department of Nephrology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
5Aletta Jacobs School of Public Health, Groningen, The Netherlands

Correspondence
Willem de Boer, Faculty of Economics and Business, University of Groningen, Groningen, AE, The Netherlands.
Email: w.i.j.de.boer@rug.nl

This study examined the association of sport participation with health outcomes and whether this relation differs between body mass index (BMI)-level subpopulations. Research outcomes for sport participation were compared with other types of leisure-time physical activity (PA). We used the Cox proportional hazards regression models to assess the associations of sport participation, and four other PA types (cycling, gardening, doing odd jobs, and walking), with the risk of prediabetes, type 2 diabetes mellitus (T2DM), and all-cause mortality in 97,212 individuals (58.4% women; mean age: 46.5 years) in the Dutch LifeLines cohort. Outcomes were stratified by three BMI levels: healthy weight (BMI: 18.5-24.9 kg/m²), overweight (BMI: 25.0-29.9 kg/m²), and obesity (BMI: 30.0 kg/m² or above). Sport participation was associated with lower health risks, but only significantly so for prediabetes (HR = 0.86, 95% CI: 0.81-0.92). For healthy weight persons, sport participation was associated with the largest risk reductions, with significantly lower risks of prediabetes (HR = 0.78, 95% CI: 0.68-0.90) and all-cause mortality (HR = 0.79, 95% CI 0.65-0.96). Other PA types were not associated with significantly lower health risks, with the exception of cycling, for which significantly lower health risks for persons with overweight were found. Our findings show that sport participation is associated with lower health risks, especially prediabetes, but the effect varies between BMI levels, with the strongest link for persons with a healthy weight. Sport participation, together with cycling, is likely to be more effective in reducing health risks than other types of PA.

KEYWORDS
body mass index, diabetes, mortality, physical activity, sports participation

1 | INTRODUCTION

The prevalence of overweight and obesity has increased rapidly over the past decades throughout the world.1 This has raised serious public health concerns because of the association between overweight and obesity and increased risk of a wide range of chronic diseases, including cardiovascular diseases, type 2 diabetes mellitus (T2DM), and all-cause mortality.2-5 It is well established that physical activity (PA) has many positive health benefits, including increased life expectancy and reduced chances of being diagnosed with cardiovascular diseases (CVD).6,8 In addition, physical inactivity has large economic consequences, including healthcare costs and productivity loss.9,10 Worldwide, PA guidelines and
policies have been established to promote PA, but with limited effect, and physical inactivity has been identified as a “pandemic” by the World Health Organization (WHO).

Although the health effects of PA in general have been studied extensively, for sport participation knowledge is limited. Several observational population studies have shown that participation in specific sports increases life expectancy and reduces risk of CVD. In addition, Koolhaas et al. found that, for middle-aged persons, sport participation is the only PA type associated with a higher health-related quality of life. These findings suggest that sport participation can be more effective in improving health than other types of PA. However, little is known about the association of sport participation with other specific health outcomes, such as the incidence of T2DM and prediabetes.

Research has also shown that the effects of PA on health outcomes can differ by socioeconomic background, lifestyle, and initial health status. PA in general has been found to significantly contribute to reducing risks of health problems and improve health for specific risk groups, such as overweight and obese individuals. Gill and Cooper found that an individual’s BMI level plays a major role in the risk of being diagnosed with T2DM. Consequently, a “one size fits all” mass-population strategy may not provide the most appropriate approach. This leads to the question to what extent sport participation is associated with lower health risks for different levels of BMI, in comparison with other types of leisure-time PA. However, to our knowledge, no study exists that investigates the relationship between sport participation and health outcomes in relation to BMI levels.

The objective of our study was to investigate the association of sport participation with the incidence of prediabetes, T2DM, and all-cause mortality, and assess this association across individuals with healthy weight, overweight, and obesity. In addition, we compared the outcomes of sport participation with those of the other types of leisure-time PA: cycling, gardening, doing odd jobs, and walking.

2 | METHODS

2.1 | Sample

The LifeLines cohort study is a large population-based cohort study and biobank of 167 729 persons living in the northern part of the Netherlands. Participants are screened through physical examination, including anthropometry. In addition, they fill in questionnaires on, among others, demographics, health status, lifestyle, and psychosocial matters. The LifeLines study is constructed conform to the Declaration of Helsinki. All participants of LifeLines signed a declaration, where he/she approved of the use of the (anonymized) data and material for scientific purposes. Baseline measurements (IA) took place from 2006 until 2013. A full-population follow-up measurement (2A) was conducted between 2014 and 2017, with new physical examinations and questionnaires for the full (surviving) population. Intermediate questionnaires (IB and IC) were conducted with an interval of around 1.5 years. From the 167 729 participants of the LifeLines study, we excluded persons under age 25, a BMI below 18.5, or with missing or implausible data for any of the variables included in our analysis. In total, 97 212 participants were eligible for our study on all-cause mortality (see flowchart Figure S1 in the Supplement). Due to a limited response to the follow-up questionnaires and glucose measurement and exclusion of persons with prediabetes at baseline (for the analysis of the incidence of prediabetes at follow-up), the remaining sample size was 76 141 for T2DM and 54 452 for prediabetes.

2.2 | Sport participation assessment and BMI

Sports participation, as well as the other types of PA (cycling, gardening, doing odd jobs, and walking), was assessed using the short questionnaire to assess health-enhancing physical activity questionnaire (SQUASH). SQUASH is a validated questionnaire that inquires participants about the frequency and duration of participation in several types of PA, including sport participation. Respondents were asked about their amount of PA in minutes per week, for a normal week in the preceding months. In SQUASH, cycling and walking are only considered part of sport participation if they were done as a leisure-time sport discipline (ie, leisure-time cycling with a racing bike or a mountain bike), while for all other purposes (such as commuting or shopping) they are categorized as the separate “cycling” and “walking” PA types. An individual can thus take part in both cycling as a sport and cycling for other purposes, but the amount of time spent participating in one or the other must be allocated to each specific PA type (in order to avoid double counting). For BMI, height and weight were measured using standard anthropometry procedures at baseline. Persons with a BMI of 18.5-24.9 kg/m² were classified as “healthy weight,” those with a BMI of 25.0-29.9 kg/m² as “overweight,” and those with a BMI of 30.0 kg/m² and higher as “obese.”

2.3 | Outcome variables

Outcome variables in our analysis were dummy variables for the incidence of prediabetes, T2DM, and all-cause mortality, measured at any time beyond baseline. Following the 2003 American Diabetes Association diagnostic criteria (ADA), participants who registered a fasting glucose from 5.6 to
6.9 mmol/L at follow-up were identified as incident cases for prediabetes. Following Dëschênes et al., participants were identified as having T2DM at a follow-up period (1B, 1C, or 2A), if they (a) self-reported a newly developed doctor-diagnosed T2DM; (b) were measured to have a fasting glucose value of 7.0 mmol/L or higher; or (c) had a hemoglobin A1c (HbA1c, the hemoglobin type that is bound to glucose) value of 6.5%. Mortality is registered in LifeLines on a monthly basis, and we used data to the end of 2019.

2.4 | Covariates

To adjust for confounding, we followed the model of Pedicic et al., which uses directed acyclic graphs to show the relation between possible confounders on sport participation and all-cause mortality risk. We believe this model is also applicable to other PA types and health outcomes. The model includes sociodemographic factors, unhealthy lifestyle, adiposity, health status, and amount of PA as confounders. For socioeconomic determinants, we included age, sex, education, and net household income in the analysis. Lifestyle variables included alcohol consumption, smoking status, and diet quality (ie, the LifeLines Diet Score). For health status, the presence of depression and burnout for mental health was included as well as doctor-diagnosed cardiovascular diseases and cancer. In addition, the amount of leisure-time was included as a covariate as well as subjective well-being (following the RAND-36 questionnaire) to account for general health status. Finally, the PA-type categories are not exclusive, that is, one person can be a participant in more than one PA type. To account for physical activities other than the one that is investigated, we calculated an physical activity score (PA Score) for each individual, based on the amount of participation in these other physical activities. Here, this covariate is calculated by multiplying the number of hours being physically active in a given PA type by the metabolic equivalent (MET), summed over all PA types except the PA type for which the health effect was being estimated. This PA Score is therefore different for every PA type.

2.5 | Analysis

In this study, we assessed the associations between sport participation (any versus none) and the incidence of prediabetes, T2DM, and all-cause mortality, for three BMI types. For this analysis, we estimated several Cox proportional hazards regression models. The Cox proportional hazards model was chosen because it can take into account the time-to-event, that is, the time between baseline measurement (1A) and the first moment of incidence; as well as time at risk, that is, the time between baseline and the last measurement (2A for prediabetes and T2DM, or the end of 2019 for morbidity). For each model, the hazard ratio was measured for participating in a certain type of PA, compared with not participating in that type of PA (with a set hazard ratio of 1). In addition, the data for each type of PA differed on one covariate: the amount of PA done on other PA types (PA Score).

First, we estimated the association of sport participation with prediabetes and T2DM incidence and all-cause mortality, with only age and sex as covariates (Model 1; see Data S1 for model specifications). This model was estimated for sport participation as well as the other PA types.

Next, a model with all covariates (as mentioned above) including BMI-level dummy variables (for overweight and obesity) was estimated (Model 2).

Finally, we estimated the association of sport participation stratified by BMI-level subpopulations (Model 3). In this model, BMI level variables were excluded, as well as non-relevant covariates, as determined by a log-rank test of equality (see Data S1 for more details). Again, we also estimated this model for the other PA types.

So, in total 15 models were estimated: The 3 types of models mentioned above were estimated for 5 different PA types. For each of the models, we present the hazard ratio (HR) for participating in a given PA type with a 95% confidence interval (CI) and P-values, with HRs with a P-value below 0.05 identified as statistically significant. Analysis was carried out with Stata 13 (Stata Corp. LLC, College Station, Texas, USA).

3 | RESULTS

3.1 | Population characteristics

Population characteristics at baseline measurement of the full dataset (for all-cause mortality) are presented in Table 1. Follow-up was on average 4.8 ± 2.1 years for both prediabetes and diabetes, corresponding to 258 147 and 357 913 person-years of survival, respectively. For all-cause mortality, follow-up was 7.7 ± 1.6 years, corresponding to 753 197 person-years. Incidence was 3547 for prediabetes, 1086 for diabetes, and 1379 for all-cause mortality (Table S1). For all three health outcomes, the incidence rate was lowest for the healthy weight category and highest for obesity.

The all-cause mortality study group was predominantly female (58.4%) with an average age of 46.5 years at baseline. Females and middle-aged persons are over-represented compared with the general population of the northern part of the Netherlands, but this is in line with the total population of LifeLines. Of the population, 43.3% was of a healthy weight (median BMI: 22.9 kg/m²), 41.0% was overweight (median BMI: 26.9 kg/m²), and 15.7% was obese (median BMI: 32.4 kg/m²). Persons with a healthy weight participated
more in sport (61.9%) than overweight persons (55.3%), while less than half (46.0%) of the obese persons participated in sport.

The all-cause mortality study group was somewhat older and included relatively more higher educated and high-income individuals than the full LifeLines dataset (see Table S2 for a more detailed breakdown of the datasets). The main reason for this is the exclusion of persons below 25 years old. For the T2DM and prediabetes study groups, the sample was to a large extent similar to the mortality study group, albeit with more females and fewer low-income individuals. This is fully the result of selection based on exclusion of persons who had, at baseline, incidence, or incomplete data for T2DM (exclusion of 21,071 individuals) or prediabetes (another 21,689 persons excluded). Males and low-income groups are known to be more at risk for these diseases.32 As with the whole

| TABLE 1 | Population characteristics at baseline, for the all-cause mortality sample, by BMI category |
|---------|---------------------------------|---------------------------------|----------------|------|------|
| Variable | Healthy weight (BMI 18.5-24.9 kg/m²) | Overweight (BMI³ 25.0-29.9 kg/m²) | Obese (BMI³ ≥30.0 kg/m²) | All |
|---------|---------------------------------|---------------------------------|----------------|------|------|
| Observations | 42,139 | 39,819 | 15,254 | 97,212 |
| Sex (% female) | 65.9 | 49.2 | 61.6 | 58.4 |
| Age | 44.3 | 48.2 | 48.0 | 46.5 |

| Education | Low (%) | High (%) | Low (%) | High (%) | Low (%) | High (%) | Low (%) | High (%) | Low (%) | High (%) |
|-----------|---------|----------|---------|----------|---------|----------|---------|----------|---------|----------|
| Low (%) | 22.2 | 32.3 | 28.5 | 23.9 | 18.9 | 17.7 | 19.2 |
| High (%) | 40.5 | 29.5 | 21.4 | 33.0 | 38.1 | 38.8 | 34.7 |

| Income | Low (<2000 Euro, %) | High (>3000 Euro, %) | Low (<2000 Euro, %) | High (>3000 Euro, %) | Low (<2000 Euro, %) | High (>3000 Euro, %) | Low (<2000 Euro, %) | High (>3000 Euro, %) | Low (<2000 Euro, %) | High (>3000 Euro, %) |
|--------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Low (%) | 23.5 | 34.8 | 22.5 | 32.9 | 23.5 | 34.8 | 19.2 | 19.2 | 19.2 | 19.2 |
| High (%) | 40.5 | 29.5 | 21.4 | 33.0 | 38.1 | 38.8 | 34.7 | 34.7 | 34.7 | 34.7 |

| Smoking | Current (%) | Former, excl. current (%) | Current (%) | Former, excl. current (%) | Current (%) | Former, excl. current (%) |
|---------|-------------|--------------------------|-------------|--------------------------|-------------|--------------------------|
| Current (%) | 20.1 | 30.0 | 18.9 | 18.9 | 18.9 | 18.9 |
| Former, excl. current (%) | 49.2 | 65.9 | 61.6 | 61.6 | 61.6 | 61.6 |

| Alcohol | No/little (<1 glass/week, %) | Heavy (≥ 5 days/week, %) | No/little (<1 glass/week, %) | Heavy (≥ 5 days/week, %) | No/little (<1 glass/week, %) | Heavy (≥ 5 days/week, %) |
|---------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|
| No/little (<1 glass/week, %) | 15.3 | 15.7 | 17.1 | 17.1 | 17.1 | 17.1 |
| Heavy (≥ 5 days/week, %) | 13.1 | 13.5 | 12.6 | 12.6 | 12.6 | 12.6 |

| Nutrition (LifeLines diet score) | Leisure-time (avg. min./week) | PA score per week (median) | Leisure-time PA³ score (median) | CVD⁵ at baseline (%) | Cancer at baseline (%) | BMI³ (median) |
|---------------------------------|-----------------|----------------|----------------|----------------|----------------|----------------|
| 24.7 | 535.2 | 115.6 | 30.5 | 7.9 | 4.6 | 22.9 |
| 24.3 | 582.3 | 117.5 | 33.0 | 9.5 | 5.3 | 26.9 |
| 23.9 | 517.8 | 109.4 | 27.0 | 11.3 | 5.2 | 32.4 |
| 24.4 | 551.8 | 115.4 | 31.0 | 9.1 | 5.0 | 25.5 |

| Explanatory variables | Sport participation (any, %) | Other types of physical activity | 61.9 | 64.5 | 59.8 | 64.5 |
|-----------------------|-----------------------------|---------------------------------|------|------|------|------|
| Sport participation (any, %) | 61.9 | 55.3 | 46.0 | 56.7 |
| Other types of physical activity | 66.3 | 64.5 | 59.8 | 64.5 |
| Cycling, not in sport (any, %) | 56.3 | 58.3 | 51.1 | 56.3 |
| Gardening (any, %) | 40.8 | 48.8 | 40.4 | 44.0 |
| Odd jobs (any, %) | 78.2 | 76.7 | 73.4 | 76.8 |

| Dependent variables | Prediabetes (ADA) at follow-up (%) | T2DM⁶ at follow-up, not baseline (%) | All-cause mortality (until 2019, %) |
|-----------------|-----------------|-----------------|-----------------|
| Prediabetes (ADA) at follow-up (%) | 3.4 | 8.1 | 13.3 | 6.5 |
| T2DM⁶ at follow-up, not baseline (%) | 0.5 | 1.6 | 3.9 | 1.4 |
| All-cause mortality (until 2019, %) | 1.0 | 1.7 | 1.8 | 1.4 |

³Body mass index.
⁴Physical activity.
⁵Cardiovascular disease.
⁶Type 2 diabetes mellitus.
LifeLines population, the risks of selection bias for the sub-populations appear to be relatively small.

### 3.2 | Sport participation

Table 2 shows the outcomes of the Cox hazard ratio regressions with age and sex as confounders (Model 1) for sport participation, as well as the other PA types. In this simple model, sport participation was associated with significant reduced risks for all health outcomes, with the largest reduced risk (HR = 0.68, 95% CI: 0.60-0.77) for T2DM. Of the other PA types, only cycling was associated with significantly lower risk for all three health outcomes.

Table 3 shows the outcomes of full-model Cox hazard ratio regressions, including BMI type as a confounder (Model 2), for sport participation on all three health outcomes. Sport participation was associated with a significantly lower risk for prediabetes (HR = 0.86, 95% CI: 0.81-0.92). For T2DM (HR = 0.88, 95% CI: 0.78-1.00) and all-cause mortality (HR = 0.91, 95% CI: 0.81-1.01), the associated risks of sport participation were also lower, but insignificant. For prediabetes and T2DM, but not mortality, overweight and obesity were significantly associated with a much higher risk of incidence, when compared to healthy weight persons.

### 3.3 | Stratification by BMI type

Table 4 shows the results of the final model (Model 3) multivariate analyses of the association with prediabetes, T2DM, and all-cause mortality for sport participation, as well as other PA types, by BMI type.

For prediabetes, sport participation was associated with risk reductions for all three BMI types. For healthy weight (HR = 0.78, 95% CI: 0.68-0.90) and overweight (HR = 0.88, 95% CI: 0.80-0.97), this reduction is significant, but not for obese persons (HR = 0.90, 95% CI: 0.79-1.03). Moreover, the difference in reduction of the prediabetes risk associated with sport participation, between persons on a healthy weight and those with obesity, was significant.

Most other PA types had hazard ratios around 1, indicating no association with lower prediabetes risks. However, for persons with overweight, cycling was associated with a significantly lower risk of prediabetes.

The full-model analysis of the associated risks of T2DM shows that sport participation is associated with lower, but not significant, T2DM risks for person with a healthy weight (HR = 0.86, 95% CI: 0.63-1.19) and overweight (HR = 0.86, 95% CI: 0.71-1.03). The HR for obesity was somewhat higher but also below 1.00 (HR = 0.93, 95% CI: 0.78-1.13). In comparison, cycling was associated with a significant lower T2DM risk for overweight persons (HR = 0.72, 95% CI: 0.59-0.87), while also having lower hazard ratios than sport participation for the other BMI types. By contrast, the other PA types had higher HRs and were not significantly associated with lower T2DM risks for any of the BMI types.

For all-cause mortality, sport participation was found to be significantly associated with lower all-cause mortality risks only for persons on a healthy weight (HR = 0.79, 95% CI: 0.65-0.96). For obesity, the association of sport participation with all-cause mortality risks was even somewhat higher than for non-participants (HR = 1.06, 95% CI: 0.83-1.36). Of the other PA types, cycling was significantly associated with lower all-cause mortality risks for all BMI types and gardening for persons on a healthy weight. The largest risk reduction associated with cycling was for obese persons (HR = 0.73, 95% CI: 0.57-0.93). For persons with obesity, all other PA types are associated with non-significant, but lower all-cause mortality risks.

### 4 | DISCUSSION

In this study, we examined the association of sport participation with prediabetes, T2DM, and all-cause mortality. Our study contributes to the small, but growing, literature on the relation between sport participation and health outcomes. By

---

**Table 2** Associations between doing physical activity (PA) at baseline and prediabetes, diabetes type 2, and all-cause mortality in adults at follow-up; hazard ratios for separate univariate model outcomes, adjusted for age and sex (Model 1), for 5 types of PA

| PA type      | Prediabetes (HR 95% CI) | T2DM (HR 95% CI) | Mortality (HR 95% CI) |
|--------------|-------------------------|-----------------|-----------------------|
| Sport participation | 0.74 (0.69-0.79)** | 0.68 (0.60-0.77)** | 0.78 (0.70-0.87)** |
| Cycling       | 0.83 (0.77-0.89)** | 0.64 (0.56-0.73)** | 0.69 (0.61-0.77)** |
| Gardening     | 0.94 (0.88-1.01) | 0.88 (0.77-0.99) | 0.80 (0.72-0.89)** |
| Odd jobs      | 0.95 (0.88-1.02) | 1.00 (0.88-1.15) | 0.91 (0.81-1.03) |
| Walking       | 0.96(0.89-1.04) | 0.82 (0.71-0.94)** | 0.89 (0.79-1.01) |

aType 2 diabetes mellitus.

bAbbreviations: HR, hazard ratio; CI, confidence interval.

*P < 0.05,

**P < 0.01, hazard ratios compared not participating in that kind of PA.
including prediabetes and T2DM, our study ventured into new but interesting territory.

Our study is the first to stratify the relation of sport participation with health outcomes by BMI types. Direct comparisons with similar stratifying strategies are thus limited.

We found that sport participation is associated with significantly reduced risks for prediabetes for the healthy weight and overweight categories; and for T2DM for overweight persons. Our study also shows that sports participation improves life expectancy and the odds for prediabetes incidence significantly more for persons with a healthy weight than those with obesity. These results, as well as additional analysis with an interaction model (see “Interactions between BMI type and sport participation” in Data S1), demonstrate that the association between sport participation and health outcomes can differ significantly between BMI types. This somewhat contradicts the findings of Lee et al., who report HRs on the association of running with all-cause mortality for persons with a BMI below 25.0 to be similar to those with a higher BMI.

| Variable                  | Prediabetes     | All-cause mortality |
|---------------------------|-----------------|---------------------|
|                           | HR (95% CI) b   |                     |
| Sport participation       | 0.86 (0.81-0.92)** | 0.91 (0.81-1.01)   |
| Sex (Female)              | 0.52 (0.49-0.56)** | 0.73 (0.65-0.82)** |
| Age                       | 1.03 (1.03-1.03)** | 1.10 (1.10-1.11)** |
| Current smoker            | 1.28 (1.17-1.41)   | 1.94 (1.65-2.27)** |
| Former smoker             | 1.05 (0.97-1.13) ** | 1.24 (1.09-1.41)** |
| No/little alcohol         | 1.05 (0.95-1.16) ** | 1.19 (1.03-1.37)** |
| High alcohol              | 1.02 (0.93-1.12) ** | 1.12 (0.98-1.28)** |
| LifeLines diet score      | 1.00 (0.99-1.00) ** | 0.97 (0.96-0.98)** |
| CVD                      | 1.21 (1.09-1.35)** | 1.36 (1.19-1.56)** |
| Cancer                   | 1.03 (0.89-1.20) ** | 2.25 (1.96-2.57)** |
| Subjective well-being    | 1.05 (1.00-1.10)** | 1.24 (1.15-1.34)** |
| Depression               | 1.25 (1.08-1.43)** | 1.38 (1.11-1.71)** |
| Education low            | 1.02 (0.94-1.10) ** | 0.81 (0.72-0.93)** |
| Education high           | 0.81 (0.74-0.89)** | 0.90 (0.78-1.05)   |
| Low income               | 1.04 (0.95-1.13) ** | 1.17 (1.03-1.33)** |
| High income              | 1.05 (0.97-1.14) ** | 0.93 (0.81-1.08) **|
| Overweight (BMI type)     | 1.90 (1.81-1.99)** | 1.04 (0.97-1.13) **|
| Obese (BMI type)         | 3.60 (3.22-4.01)** | 1.09 (1.01-1.19)** |

Table 3 Model outcomes (hazard ratios) for the associations between sport participation and prediabetes, diabetes type 2, and all-cause mortality (Model 2)

- Type 2 diabetes mellitus.
- HR, hazard ratio; CI, confidence interval.
- Cardiovascular disease.
- Body mass index.
- \( P \) < 0.05.
- \( **P \) < 0.01.
However, the type of sport activity may be a factor that could explain differences in the BMI-level-specific associations with health outcomes. Further analysis for sport disciplines should clarify this.

The population size and design (including actual health outcome measurements) of LifeLines and the amount of information on PA types and covariates were important strengths of our study. Although our research followed the concepts of other studies, we added several new covariates in our analysis, including a diet quality score, subjective well-being (both significant), and the amount of leisure-time (not significant).

In our study, sport participation was associated with lower all-cause mortality, which is in agreement with the findings of several other studies. However, this finding was not statistically significant. We also compared sport participation with other PA types. Our findings suggest that sport participation may be more effective in reducing health risks than other PAs, with the exception of cycling. Cycling was associated with significant and large reductions of between 18% and 27% in all-cause mortality risk. This is somewhat higher than the 10% found in the systematic review of Kelly et al. In contrast to other research, we found no evidence for a health impact of walking.

Our research has several limitations. First of all, the relatively low number of incidence, especially when stratifying for BMI types, leads to a somewhat weak statistical power of the outcomes. With more observations or a longer follow-up period, outcomes are likely to include more significant results. Second, we must take into account that BMI, sport participation, and health are not independent. For instance, a high BMI can lead to reduce the possibilities to participate in (specific) sports, but also be the result of (previous) sport behavior. Therefore, sport participation is not independent from the health outcomes, and—although we control for various health indicators at baseline—conclusions about causality cannot be drawn. In addition, although BMI is a frequently used measure for assessing overweight and obesity, it does not distinguish between lean and fat mass, which is also relevant for studies examining the effect of PA. Third, the cross-sectional nature of baseline and follow-up measurements cannot account for changes in sport behavior between measurements. Given the data, we are only able to estimate the effects of doing PA at baseline and cannot estimate the effects of changes in sport or PA status. The estimated health effects may in part be affected by changes in PA. Gabrys et al

| TABLE 4 | Outcomes of the Cox proportional hazard regression models for the association of sport participation, and other types of PA, with prediabetes, T2DM, and all-cause mortality: hazard ratios for separate univariate models, stratified by BMI type (Model 3), for 5 types of PA |
|----------------------|----------------------|----------------------|
|                      | Healthy weight (BMIa 18.5-24.9) | Overweight (BMIa 25.0-29.9) | Obese (BMIa 30.0 and higher) |
|                      | HR (95% CI)b | HR (95% CI)b | HR (95% CI)b |
| Prediabetes | | | |
| Sport participation | 0.78 (0.68-0.90)** | 0.88 (0.80-0.97)** | 0.90 (0.79-1.03) |
| Cycling | 1.05 (0.89-1.23) | 0.89 (0.81-0.99)* | 0.90 (0.78-1.04) |
| Gardening | 0.89 (0.77-1.02) | 1.06 (0.97-1.17) | 0.99 (0.86-1.13) |
| Odd jobs | 1.00 (0.86-1.16) | 0.92 (0.83-1.02) | 1.00 (0.87-1.16) |
| Walking | 1.06 (0.89-1.25) | 1.05 (0.94-1.17) | 1.00 (0.86-1.16) |
| T2DMc | | | |
| Sport participation | 0.86 (0.63-1.19) | 0.86 (0.71-1.03) | 0.93 (0.76-1.13) |
| Cycling | 0.73 (0.52-1.04) | 0.72 (0.59-0.87)** | 0.87 (0.71-1.07) |
| Gardening | 1.12 (0.81-1.54) | 0.92 (0.76-1.10) | 1.06 (0.87-1.28) |
| Odd jobs | 0.98 (0.69-1.38) | 0.89 (0.73-1.09) | 1.37 (1.11-1.70)** |
| Walking | 0.98 (0.66-1.44) | 1.01 (0.82-1.25) | 0.90 (0.73-1.11) |
| All-cause mortality | | | |
| Sport participation | 0.79 (0.65-0.96)* | 0.94 (0.80-1.10) | 1.06 (0.83-1.36) |
| Cycling | 0.78 (0.63-0.98)* | 0.82 (0.70-0.98)* | 0.73 (0.57-0.93)* |
| Gardening | 0.77 (0.63-0.94)** | 0.94 (0.80-1.10) | 0.83 (0.65-1.06) |
| Odd jobs | 0.89 (0.72-1.10) | 1.00 (0.85-1.19) | 0.81 (0.62-1.07) |
| Walking | 1.00 (0.79-1.27) | 1.00 (0.84-1.20) | 0.83 (0.64-1.07) |

*aBody mass index.
*bHR, hazard ratio; CI, confidence interval.
*cType 2 diabetes mellitus.
*P < 0.05,
**P < 0.01, hazard ratios compared not participating in that kind of PA.
find that becoming active in sports reduces risks of cardio-metabolic diseases, while stopping increases those risks. Since decreases in PA may lead to increased risks for all-cause mortality and sport participation generally declines with age, it is plausible that our findings are likely to be underestimated of the health effects of sport participation for persons that keep participating, but may overestimate the health effects for “quitters.” Fourth, we do not take the number of hours or intensity of sport participation into account, which may lead to over- or underestimation of its association with health risks. However, regarding the dose-effect relationship of sport participation, research has been ambiguous. While some studies find positive dose-response associations for PA in general, others show no dose effects or even negative effects for very high volumes of PA. Fifth, we do not control for several unavailable potential confounding variables, such as DNA or diseases that may influence the health outcomes (mortality in particular). This may lead to research outcomes that are an over- or underestimation the actual association between PA and health outcomes. However, the findings presented here do seem to be robust. Models for several age-specific subgroups (such as 30+, 40+, and 50- to 75-year-olds) showed very similar outcomes. This is also true for when replacing the current time-specific hazard model with an age-specific hazard model (following the approach of, eg, Lamarca et al). Finally, we are aware that sport participation is very heterogeneous concept, in terms of volume, intensity, type, and context, and many other aspects. For BMI types, there could be a selection bias, that is, persons with a low BMI participate differently in sport and other types of sport (or PA) than obese persons. Moreover, since low BMI sport participants have, for instance, a large metabolic capacity, this can both directly and indirectly (through sports) influence an individual’s health risks. Further investigation of the diverse aspects of participating in sport (ie, type, volume, and intensity) is necessary to get a better understanding of the mechanisms at work between sport participation and health outcomes.

Future research, for example, using an instrumental variables approach, should also look at the causal relationship of sport participation on health effects, especially for specific (risk-related) subpopulations. This enhances the knowledge on the health effects of sport participation for specific groups and may lead to improved, more personalized, advice on health behaviors.

5 | PERSPECTIVES

Our research showed that sport participation is associated with reductions in the risks of prediabetes in particular, as well as T2DM and morbidity. By stratifying by BMI type, we found that the effects of sport participation on health outcomes were not similar across the population. Sport participation was associated with a significantly higher life expectation and significantly lower risks of prediabetes for persons with a healthy weight, especially compared with obese persons. Hence, sport participation seems to be most beneficial for persons on a healthy weight.

Sport participation is more associated with larger reductions in health risks than all other PA types, with the exception of cycling, which seems to be especially beneficial in relation to all-cause mortality as well as for overweight persons.

These results suggest that PA advice (and guidelines) should be personalized, depending on an individual’s current BMI status and health objective. For example, a person with a healthy weight may be advised to do sport for diabetes prevention, while cycling would be advisable for an overweight individual. Our findings may help to contribute to the knowledge on health effects of sport participation and PA and help to improve public health for specific subpopulations.

ACKNOWLEDGEMENTS

The authors would like to thank the LifeLines participants and the staff of the LifeLines study site, Groningen, for their collaboration. There were no sources of funding for this research.

DATA AVAILABILITY STATEMENT

Researchers can apply for data by submitting a proposal to the LifeLines Research Office (LLscience@umcg.nl). The LifeLines website provides information on the application process (http://www.lifelines.nl).

ORCID

Willem de Boer © https://orcid.org/0000-0003-1823-7607

REFERENCES

1. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the global burden of disease study 2013. The Lancet. 2014;384(9945):766-781.
2. Aune D, Sen A, Prasad M, et al. BMI and all cause mortality: systematic review and non-linear dose-response meta-analysis of 230 cohort studies with 3.74 million deaths among 30.3 million participants. BMJ. 2016;353:i2156.
3. Meigs JB, Wilson PW, Fox CS, et al. Body mass index, metabolic syndrome, and risk of type 2 diabetes or cardiovascular disease. J Clin Endocrinol Metab. 2006;91(8):2906-2912.
4. Prospective Studies Collaboration. Body-mass index and cause-specific mortality in 900 000 adults: Collaborative analyses of 57 prospective studies. The Lancet. 2009;373(9669):1083-1096.
5. He XZ, Baker DW. Body mass index, physical activity, and the risk of decline in overall health and physical functioning in late middle age. Am J Public Health. 2004;94(9):1567-1573.
6. Cosentino F, Grant PJ, Aboyans V, et al. 2019 ESC guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: the task force for diabetes, pre-diabetes, and cardiovascular diseases of the European society of cardiology (ESC) and the European association for the study of diabetes (EASD). *Eur Heart J*. 2020;41(2):255-323.

7. Geiss LS, James C, Gregg EW, Albright A, Williamson DF, Cowie CC. Diabetes risk reduction behaviors among US adults with pre-diabetes. *Am J Prev Med*. 2010;38(4):403-409.

8. Koolhaas CM, Dhana K, Schoufour JD, Ikram MA, Kavousi M, Franco OH. Impact of physical activity on the association of overweight and obesity with cardiovascular disease: the Rotterdam study. *Eur J Prev Cardiol*. 2017;24(9):934-941.

9. de Boer WIJ, Dekker LH, Koning RH, Navis GJ, Mierau JO. How are lifestyle factors associated with socioeconomic differences in health care costs? evidence from full population data in The Netherlands. *Prev Med*. 2020;130:105929.

10. Ding D, Lawson KD, Kolbe-Alexander TL, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *The Lancet*. 2016;388(10051):1311-1324.

11. Khan KM, Thompson AM, Blair SN, et al. Sport and exercise as contributors to the health of nations. *The Lancet*. 2012;380(9836):59-64.

12. Haskell WL, Blair SN, Hill JO. Physical activity: health outcomes and importance for public health policy. *Prev Med*. 2009;49(4):280-282.

13. Kohl HW, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. *The Lancet*. 2012;380(9838):294-305.

14. Oja P, Titze S, Kokko S, et al. Health benefits of different sport disciplines for adults: systematic review of observational and intervention studies with meta-analysis. *Br J Sports Med*. 2015;49(7):434-440.

15. Pedisic Z, Shrestha N, Kovalchik S, et al. Is running associated with a lower risk of all-cause, cardiovascular and cancer mortality, and is the more the better? a systematic review and meta-analysis. *Br J Sports Med*. 2020;54(15):898-905.

16. Oja P, Kelly P, Pedisic Z, et al. Associations of specific types of sports and exercise with all-cause and cardiovascular-disease mortality: a cohort study of 80 306 British adults. *Br J Sports Med*. 2017;51(10):812-817.

17. Koolhaas CM, Dhana K, Van Rooij F, Schoufour J, Hofman A, Franco O. Physical activity types and health-related quality of life among middle-aged and elderly adults: the rotterdam study. *J Nutr Health Aging*. 2018;22(2):246-253.

18. Goodpaster BH, DeLany JP, Otto AD, et al. Effects of diet and physical activity interventions on weight loss and cardiometabolic risk factors in severely obese adults: a randomized trial. *JAMA*. 2010;304(16):1795-1802.

19. Cavill N, Biddle S, Sallis JF. Health enhancing physical activity for young people: statement of the United Kingdom expert consensus conference. *Pediatr Exerc Sci*. 2001;13(1):12-25.

20. Oja P, Titze S. Physical activity recommendations for public health: development and policy context. *EPMA J*. 2011;2(3):253-259.

21. Expert Panel Members, Jensen MD, Ryan DH, et al. Executive summary: guidelines (2013) for the management of overweight and obesity in adults: A report of the american college of cardiology/american heart association task force on practice guidelines and the obesity society published by the obesity society and american college of cardiology/american heart association task force on practice guidelines. based on a systematic review from the obesity expert panel. *Obesity*. 2013;22(S2):S5-S39.

22. Gill JM, Cooper AR. Physical activity and prevention of type 2 diabetes mellitus. *Sports Med*. 2008;38(10):807-824.

23. O’Hagan C, De Vito G, Boreham CA. Exercise prescription in the treatment of type 2 diabetes mellitus. *Sports Med*. 2013;43(1):39-49.

24. Loureiro ML, Nagya RM Jr. Obesity, weight loss, and physician’s advice. *Soc Sci Med*. 2006;62(10):2458-2468.

25. Scholten S, Smidt N, Swertz MA, et al. Cohort profile: lifelines, a three-generation cohort study and biobank. *Int J Epidemiol*. 2015;44(4):1172-1180.

26. Wendel-Vos GW, Schuit AJ, Saris WH, Kromhout D. Reproducibility and relative validity of the self-questionnaire to assess health-enhancing physical activity. *J Clin Epidemiol*. 2003;56(12):1163-1169.

27. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate hyperglycaemia: report of a WHO/IDF Consultation; 2006.

28. Deschênes SS, Burns RJ, Schmitz N. Comorbid depressive and anxiety symptoms and the risk of type 2 diabetes: findings from the lifelines cohort study. *J Affect Disord*. 2018;238:24-31.

29. Dekker LH, Rijnks RH, Strijker D, Navis GJ. A spatial analysis of dietary patterns in a large representative population in the north of the netherlands–the lifelines cohort study. *Int J Behav Nutr Phys Act*. 2017;14(1):166.

30. Hays RD, Morales LS. The RAND-36 measure of health-related quality of life. *Ann Med*. 2001;33(5):350-357.

31. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2010 compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc*. 2011;43(8):1575-1581.

32. Kavanagh A, Bentley RJ, Turrell G, Shaw J, Dunstan D, Subramanian S. Socioeconomic position, gender, health behaviours and biomarkers of cardiovascular disease and diabetes. *Soc Sci Med*. 2010;71(6):1150-1160.

33. Kljic B, Scholten S, Mandemakers JJ, Snieder H, Stolk RP, Smidt N. Representativeness of the LifeLines cohort study. *PLoS One*. 2015;10(9):e0137203.

34. Lee D, Pate RR, Lavie CJ, Sui X, Church TS, Blair SN. Leisure-time running reduces all-cause and cardiovascular mortality risk. *Am Coll Cardiol*. 2014;64(5):472-481.

35. Andersen LB, Schnohr P, Schroll M, Hein HO. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Arch Intern Med*. 2000;160(11):1621-1628.

36. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose–response meta-analysis of cohort studies. *Int J Epidemiol*. 2011;40(5):1382-1400.

37. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *Int J Behav Nutr Phys Act*. 2014;11(1):132.

38. Gabrys L, Baumert J, Heidemann C, Busch M, Finger JD. Sports activity patterns and cardio-metabolic health over time among adults in Germany: results of a nationwide 12-year follow-up study. *J Sport Health Sci*. 2020.

39. Huang Y, Jiang C, Xu L, et al. Mortality in relation to changes in physical activity in middle-aged to older Chinese: an 8-year follow-up of the Guangzhou Biobank cohort study. *J Sport Health Sci*. 2020.
40. Eime RM, Harvey JT, Charity MJ, Casey MM, Westerbeek H, Payne WR. Age profiles of sport participants. *BMC Sports Sci Med Rehabil.* 2016;8(1):6.

41. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. *CMAJ.* 2006;174(6):801-809.

42. Byambasukh O, Zelle D, Corpeleijn E. Physical activity, fatty liver, and glucose metabolism over the life course: the lifelines cohort. *Am J Gastroenterol.* 2019;114(6):907-915.

43. Lamarca R, Alonso J, Gomez G, Muñoz Á. Left-truncated data with age as time scale: an alternative for survival analysis in the elderly population. *J Gerontol A Biol Sci Med Sci.* 1998;53(5):M337-M343.

44. Kujala UM, Marti P, Kaprio J, Herrelahti M, Tikkanen H, Sarna S. Occurrence of chronic disease in former top-level athletes. *Sports Med.* 2003;33(8):553-561.

45. Karvinen S, Waller K, Silvennoinen M, et al. Physical activity in adulthood: genes and mortality. *Sci Rep.* 2015;5:18259.

**SUPPORTING INFORMATION**

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

**How to cite this article:** de Boer W, Corpeleijn E, Dekker L, Mierau J, Koning R. How is sport participation related to mortality, diabetes and prediabetes for different body mass index levels?. *Scand J Med Sci Sports.* 2021;00:1–10. [https://doi.org/10.1111/sms.13940](https://doi.org/10.1111/sms.13940)