Walking speed and the risk of type 2 diabetes: a systematic review and meta-analysis

Ahmad Jayedi, Mahdieh-Sadat Zargar, Alireza Emadi, Dagfinn Aune

Jayedi A, *et al. Br J Sports Med* 2023;0:1–11. doi: 10.1136/bjsports-2023-107336

eText 1. Instructions to rate the certainty of evidence using the GRADE approach.

We evaluated the certainty of evidence for each association using the updated Grading of Recommendations Assessment, Development and Evaluations (GRADE) tools [1]. We used the updated GRADE tool, which integrates the application of ROBINS-I [2, 3]. GRADE rates the certainty of evidence as high, moderate, low, or very low. [4] Randomized controlled trials start as high certainty evidence that can then be downgraded based on pre-specified criteria. In the updated GRADE tool, observational studies also start at a high certainty of evidence level. The criteria to upgrade evidence include large effect size and dose-response gradient. The criteria used to downgrade evidence include:

Study limitations- as assessed by ROBINS-I tool [5] for cohort studies.

Inconsistency- substantial between-study heterogeneity, $I^2 \geq 50\%$ and $P_{heterogeneity} < 0.10$), which remained unexplained in pre-specified subgroup and sensitivity analyses [6].

Indirectness- presence of population, intervention or comparator factors that limit the generalizability of the results [7].

Imprecision- the 95% CIs are wide, the optimal information size was not met, or the point estimate does not surpass the minimally important difference [8]. To determine the presence of imprecision, we considered the optimal information size (the number of cases included in the review compared with the number required by a conventional sample size calculation for a single adequately powered trial). On the basis of a 5% event rate in the control group and a 25 % relative risk reduction, we calculated the optional information size to be 400 cases [8]. We considered a 2% absolute risk reduction, proposed by the GRADE working group for nonfatal outcomes [9], as minimally important difference threshold. We adapted a recently published GRADE minimally contextualized approach to rate for imprecision based on minimally important difference [10, 11]. Accordingly, we considered whether the point estimate of effect size was greater than or less than the minimally important difference, and whether the 95% confidence interval overlapped that threshold. To calculate absolute effect, we estimated risk difference and its 95%CI using the pooled relative risk. We calculated pooled relative risk and then converted the pooled relative risk to risk difference using baseline risk [12]. Baseline risk was estimated using the average event rate across included cohort studies.

Publication bias- compelling evidence of publication bias [13].

eTable 1. Literature search and study selection process.

PubMed (305)
1. "Walking speed" [all fields] OR "walking pace" [all fields] OR "gait speed" [all fields] OR "gait pace" [all fields] or "step intensity" [all fields]
2. Diabetes Mellitus [Mesh] OR Diabetes Mellitus, Type 2 [Mesh] OR diabetes [ti/ab] OR diabetic [ti/ab]
3. Prospective [all fields] OR retrospective [all fields] OR cohort* [all fields] OR follow-up [all fields] OR longitudinal [all fields] OR observational [all fields] OR nested [all fields] OR case-control [all fields] OR case-cohort [all fields] OR "relative risk" [all fields] OR "risk ratio" [all fields] OR "rate ratio" [all fields] OR "hazard ratio" [all fields] OR "odds ratio" [all fields]
4. #1 AND #2 AND #3
Scopus (1203)
CENTRAL (542)
Web of Science (356)
Total: 2406

Jayedi A, *et al. Br J Sports Med* 2023;0:1–11. doi: 10.1136/bjsports-2023-107336

eTable 2. Description of the ICEMAN domains and how to judge each domain.

1: Is the analysis of effect modification based on comparison within rather than between trials?			
Completely between	Mostly between or unclear	Mostly within	Completely within
Subgroup analysis or meta-regression comparing overall effects of each individual trial. This is typical for aggregate data meta-analysis.	Subgroup analysis or meta-regression with most information coming from overall effects, but some trials providing within-trial subgroup information	Most trials providing within-trial subgroup information; or individual participant data analysis that combines within and between trial information	All trials providing within-trial subgroup information or individual participant data; and the analysis separates within from between trial information, e.g. meta-analysis of interactions
2: For within-trial comparisons, is the effect modification similar from trial to trial? Not applicable: no or one within-RCT comparison			
Definitely not similar	Probably not similar or unclear	Mostly similar	Definitely similar
Effect modification reported for two or more trials and clearly different directions	Effect modification not reported for individual trials or too imprecise to tell	Effect modification reported for two or more trials, mostly similar in direction, but considerable differences in magnitude	Effect modification reported for two or more trials, similar in direction, only some differences in magnitude
3: For between-trial comparisons, is the number of trials large? [ ] Not applicable: no between RCT comparison			
Very small	Rather small or unclear	Rather large	Large
1 or 2 or in smallest subgroup; 5 or less in continuous meta-regression	3-4 in smallest subgroup; 6-10 in continuous meta-regression	5-9 in smallest subgroup; 11 to 15in continuous meta-regression	10 or more in smallest subgroup; more than 15 in continuous meta-regression
4: Was the direction of effect modification correctly hypothesized a priori?			
Definitely no	Probably no or unclear	Probably yes	Definitely yes
Clearly post-hoc or results inconsistent with hypothesized direction or biologically very implausible	Vague hypothesis or hypothesized direction unclear	No prior protocol available but unequivocal statement of a priori hypothesis with correct direction of effect modification	Prior protocol available and includes correct specification of direction of effect modification, e.g. based on a biologic rationale
5: Does a test for interaction suggest that chance is an unlikely explanation of the apparent effect modification? (consider irrespective of number of effect modifiers)			
Chance a very likely explanation	Chance a likely explanation or unclear	Chance may not explain	Chance an unlikely explanation
Interaction or meta-regression p-value >0.05	Interaction or meta-regression p-value ≤0.05 and >0.01, or no test of interaction reported and not computable	Interaction or meta-regression p-value ≤0.01 and >0.005	Interaction or meta-regression p-value ≤0.005
6: Did the authors test only a small number of effect modifiers or consider the number in their statistical analysis?			
Definitely no	Probably no or unclear	Probably yes	Definitely yes
Explicitly exploratory analysis or large number of effect modifiers tested (e.g. greater than 10) and multiplicity not considered in analysis	No mention of number or 4-10 effect modifiers tested and number not considered in analysis	No protocol available but unequivocal statement of 3 or fewer effect modifiers tested	Protocol available and 3 or fewer effect modifiers tested or number considered in analysis
7: Did the authors use a random effects model?			
Definitely no	Probably no or unclear	Probably yes	Definitely yes
Fixed (or common) effect or	Probably fixed effect(s) model	Probably random (or mixed)	Random (or mixed) effects

fixed effects model explicitly stated		effects	explicitly stated
8: If the effect modifier is a continuous variable, were arbitrary cut points avoided? [ ] not applicable: not continuous			
Definitely no	Probably no or unclear	Probably yes	Definitely yes
Analysis based on exploratory cut point(s), e.g. picking cut point associated with highest interaction p-value	Analysis based on cut point(s) of unclear origin	Analysis based on pre-specified cut point(s), e.g. suggested by prior RCT	Analysis based on the full continuum, e.g. assuming a linear or logarithmic relationship
9 Optional: Are there any additional considerations that may increase or decrease credibility? (manual section 3.9) [ ] not applicable			
yes, probably decrease		yes, probably increase	
10. How would you rate the overall credibility of the proposed effect modification? Overall rating: The overall rating should be derived by the items that decrease credibility: **Very low**: All responses definitely or probably decrease credibility or unclear **Maximum usually low**: Two or more responses definitely decrease credibility even if all other responses satisfy credibility criteria **Maximum usually moderate**: One response definitely decreases credibility even if all other responses satisfy credibility criteria **Maximum usually moderate**: Two responses probably decrease credibility even if all other responses satisfy credibility criteria **High very likely**: No response options definitely or probably decrease credibility			
11. How would you interpreted the overall credibility of the proposed effect modification? **Very low**: Very likely no effect modification. Use overall effect for each subgroup. **Maximum usually low**: Likely no effect modification. Use overall effect for each subgroup but note remaining uncertainty. **Maximum usually moderate**: Likely effect modification. Use separate effect for each subgroup but note remaining uncertainty. **High very likely**: Very likely effect modification. Use separate effect for each subgroup.			

eTable 3. List of studies which were excluded based on full text assessment.

1. Not relevant exposure (n=61) [14-74]
2. Review study (n=8) [75-82]
3. Not relevant outcome (n=2) [83, 84]
4. Duplicate publication (n=1) [85]
5. Cross-sectional (n=1) [86]
6. Patient-based cohort (n=1) [87]

eTable 4. ROBINS-I judgement for each domain and overall for studies included in meta-analysis of walking speed and the risk of type 2 diabetes.

Study	Bias due to confounding	Bias due to selection of participants	Bias due to exposure assessment	Bias due to misclassification during follow-up	Bias due to missing data	Bias due to measurement of the outcome	Bias due to selective reporting of the results	Overall judgement
Boonpor, 2022	Serious	Low	Serious	Low	Low	Low	Low	Serious
Cuthbertson, 2022	Serious	Low	Low	Low	Low	Low	Low	Serious
Hu, 1999	Moderate	Moderate	Serious	Low	Low	Moderate	Low	Serious
Hu, 2001	Moderate	Moderate	Serious	Low	Low	Moderate	Low	Serious
Iwasaki, 2021	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Joseph, 2016	Serious	Low	Serious	Low	Low	Low	Low	Serious
Kaplan, 2022	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Krishnan, 2008	Serious	Low	Serious	Low	Low	Serious	Low	Serious
Master, 2022	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Nakanishi, 2004	Serious	Low	Low	Low	Low	Low	Low	Serious

eTable 5. Assessment of credibility of subgroup difference for the association of average/normal walking and the risk of type 2 diabetes based on ICEMAN.

Variable	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Overall credibility
Walking speed assessment	Completely between	Mostly similar	Rather large	Definitely yes	Chance a likely explanation	Definitely yes	Definitely yes	Not applicable	Moderate
Diagnosis of type 2 diabetes	Completely between	Mostly similar	Rather small	Definitely yes	Chance a likely explanation	Definitely yes	Definitely yes	Not applicable	Moderate
Risk of bias	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Region	Completely between	Mostly similar	Very small	Definitely no	Chance an unlikely explanation	Probably no	Definitely yes	Not applicable	Low
Number of cases	Completely between	Mostly similar	Rather large	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Definitely yes	Low
Follow-up duration	Completely between	Mostly similar	Rather large	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Definitely yes	Low
Sex	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Definitely yes	Low
Adjustments									
Total physical activity	Completely between	Mostly similar	Rather large	Definitely yes	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Time spent walking per day or step count per day	Completely between	Mostly similar	Rather small	Definitely yes	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Smoking status	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Definitely yes	Definitely yes	Not applicable	Low
Alcohol drinking	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Blood pressure	Completely between	Mostly similar	Rather large	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Body mass index	Completely between	Mostly similar	Rather large	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Family history of diabetes	Completely between	Mostly similar	Rather small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low

Q, question; Q1, Is the analysis of effect modification based on comparison within rather than between trials? Q2, For within-trial comparisons, is the effect modification similar from trial to trial? Q3, For between-trial comparisons, is the number of trials large? Q4, Was the direction of the effect modification

correctly hypothesized priori? Q5, Does a test for interaction suggest that chance is an unlikely explanation of the apparent effect modification? Q6, Did the authors test only a small number of effect modifiers? Q7, Did the authors use a random effects model? Q8, If the effect modifier is a continuous variable, were arbitrary cut points avoided?

eTable 6. Subgroup analyses of the association between brisk/striding walking and the risk of type 2 diabetes.

Variables	Number of cohorts	Relative risk (95%CI)	I^2, $P_{heterogeneity}$	P subgroup difference
All cohorts	6	0.61 (0.49, 0.73)	81%, <0.001	-
Risk of bias				
Moderate	1	1.05 (0.69, 1.41)	-	0.01
Serious	5	0.57 (0.46, 0.69)	81%, <0.001	
Region				0.35
US	5	0.64 (0.46, 0.83)	85%, <0.001	
Europe	1	0.55 (0.49, 0.61)	-	
Sex				<0.001
Male	2	0.46 (0.33, 0.59)	73%, 0.05	
Female	2	0.75 (0.70, 0.80)	0%, 0.44	
Both	3	0.72 (0.50, 0.94)	57%, 0.10	
Follow-up duration				0.74
<8 years	2	0.55 (0.49, 0.61)	0%, 0.94	
≥8 years	4	0.66 (0.44, 0.88)	89%, <0.001	
Number of cases				0.08
<1000	2	0.82 (0.46, 1.19)	72%, 0.06	
≥1000	4	0.55 (0.42, 0.68)	82%, <0.001	
Walking speed assessment				0.40
Measured	2	0.79 (0.31, 1.27)	78%, 0.03	
Self-reported	4	0.57 (0.45, 0.70)	85%, <0.001	
Type 2 diabetes assessment				0.58
Medical records or measured	4	0.65 (0.50, 0.80)	66%, 0.03	
Self-reported	2	0.55 (0.24, 0.86)	94%, <0.001	
Adjustments				
Body mass index				0.08
Yes	2	0.48 (0.32, 0.63)	87%, 0.01	
No	5	0.66 (0.52, 0.79)	76%, <0.001	
Total physical activity				0.24
Yes	3	0.53 (0.33, 0.73)	79%, 0.01	
No	3	0.70 (0.51, 0.88)	83%, <0.001	
Time spent walking or step count per day				0.97
Yes	2	0.62 (0.47, 0.78)	83%, 0.02	
No	4	0.63 (0.39, 0.86)	83%, ,0.001	
Smoking status				-
Yes	6	0.61 (0.49, 0.73)	81%, <0.001	
No	-	-	-	
Alcohol drinking				0.51
Yes	5	0.60 (0.46, 0.74)	84%, <0.001	
No	1	0.67 (0.52, 0.82)	-	
Blood pressure				0.17
Yes	2	0.82 (0.46, 1.19)	72%, 0.06	
No	4	0.55 (0.42, 0.68)	83%, <0.001	
Family history of diabetes				0.58
Yes	2	0.55 (0.24, 0.86)	94%, <0.001	

No	4	0.65 (0.50, 0.80)	66%, 0.03	
Studies that reported relative risk both before and after adjustment for body mass index				0.49
Yes	1	0.52 (0.46, 0.58)	-	
No	1	0.55 (0.49, 0.61)	-	

eTable 7. Assessment of credibility of subgroup difference for the association of brisk/striding walking and the risk of type 2 diabetes based on ICEMAN.

Variable	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Overall credibility
Walking speed assessment	Completely between	Mostly similar	Very small	Definitely yes	Chance a very likely explanation	Definitely yes	Definitely yes	Not applicable	Low
Diagnosis of type 2 diabetes	Completely between	Mostly similar	Very small	Definitely yes	Chance a very likely explanation	Definitely yes	Definitely yes	Not applicable	Low
Risk of bias	Completely between	Mostly similar	Very small	Definitely no	Chance a likely explanation	Probably no	Definitely yes	Not applicable	Low
Region	Completely between	Mostly similar	Very small	Definitely no	Chance an unlikely explanation	Probably no	Definitely yes	Not applicable	Low
Number of cases	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Definitely yes	Low
Follow-up duration	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Definitely yes	Low
Sex	Completely between	Mostly similar	Very small	Definitely no	Chance an unlikely explanation	Probably no	Definitely yes	Definitely yes	Low
Adjustments									
Total physical activity	Completely between	Mostly similar	Very small	Definitely yes	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Time spent walking or step count per day	Completely between	Mostly similar	Very small	Definitely yes	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Smoking status	-	-	-	-	-	-	-	-	-
Alcohol drinking	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Blood pressure	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Body mass index	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low
Family history of diabetes	Completely between	Mostly similar	Very small	Definitely no	Chance a very likely explanation	Probably no	Definitely yes	Not applicable	Low

Q, question; Q1, Is the analysis of effect modification based on comparison within rather than between trials? Q2, For within-trial comparisons, is the effect modification similar from trial to trial? Q3, For between-trial comparisons, is the number of trials large? Q4, Was the direction of the

effect modification correctly hypothesized priori? Q5, Does a test for interaction suggest that chance is an unlikely explanation of the apparent effect modification? Q6, Did the authors test only a small number of effect modifiers? Q7, Did the authors use a random effects model? Q8, If the effect modifier is a continuous variable, were arbitrary cut points avoided?

eTable 8 . GRADE evidence table for the association between walking speed and the risk of type 2 diabetes.

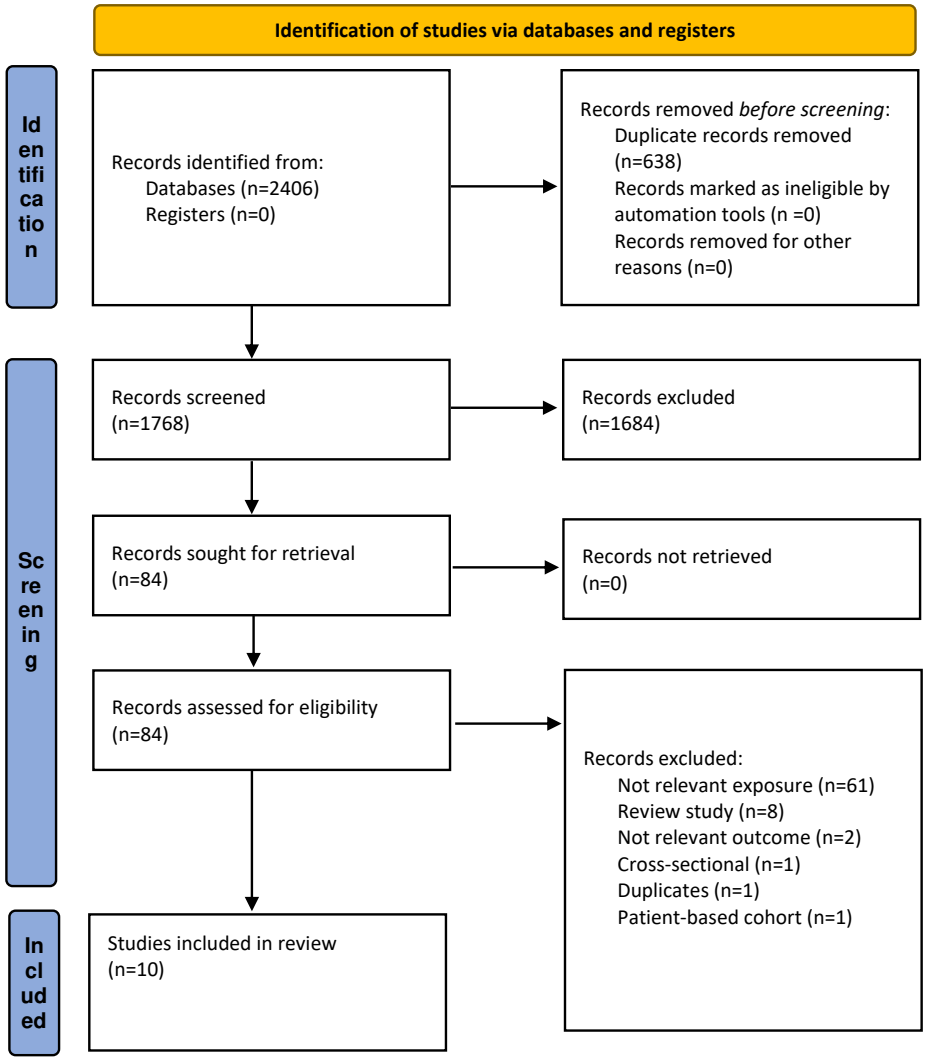
Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Participants	Cases (%)	Relative (95% CI)	Absolute (95% CI)		
Average or normal walking												
4	observational studies	very serious[a]	serious[b]	not serious	serious[c]	Dose-response gradient	160,321	6520 (4.07%)	**RR 0.85** (0.70 to 1.00)	**0.86 fewer per 100** (from 1.72 fewer to 0 fewer)	⊕⊕◯◯ Low	CRITICAL
Fairly brisk walking												
10	observational studies	very serious[d]	not serious[e]	not serious	serious[f]	Dose-response gradient	539,793	18,117 (3.4%)	**RR 0.76** (0.65 to 0.87)	**1.38 fewer per 100** (from 2.01 fewer to 0.75 fewer)	⊕⊕◯◯ Low	CRITICAL
Brisk/striding walking												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Participants	Cases (%)	Relative (95% CI)	Absolute (95% CI)		
6	observational studies	very serious[g]	not serious[h]	not serious	not serious[i]	Dose-response gradient	202,223	10,438 (5.16%)	**RR 0.61** (0.49 to 0.73)	**2.24 fewer per 100** (from 2.93 fewer to 1.55 fewer)	⊕⊕⊕◯ Moderate	CRITICAL

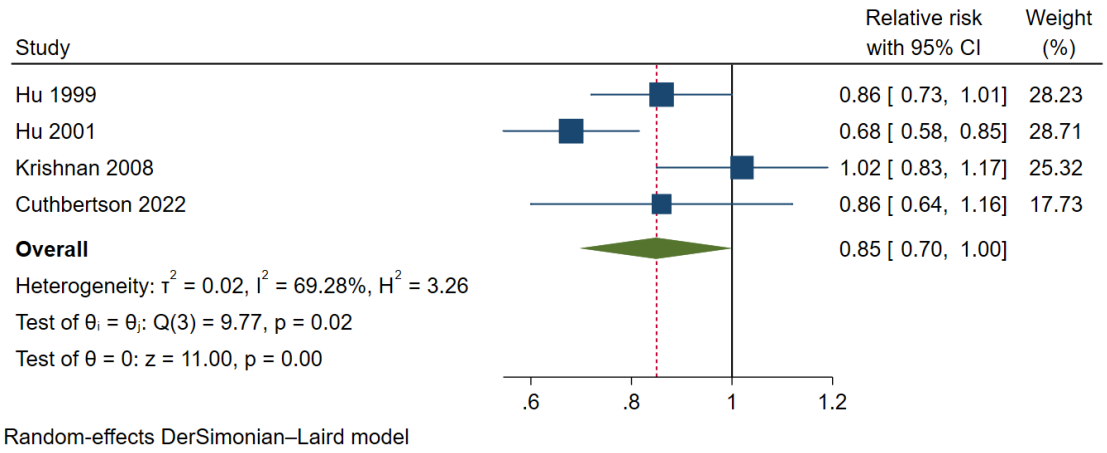
CI: confidence interval; **RR:** relative risk,

Explanations

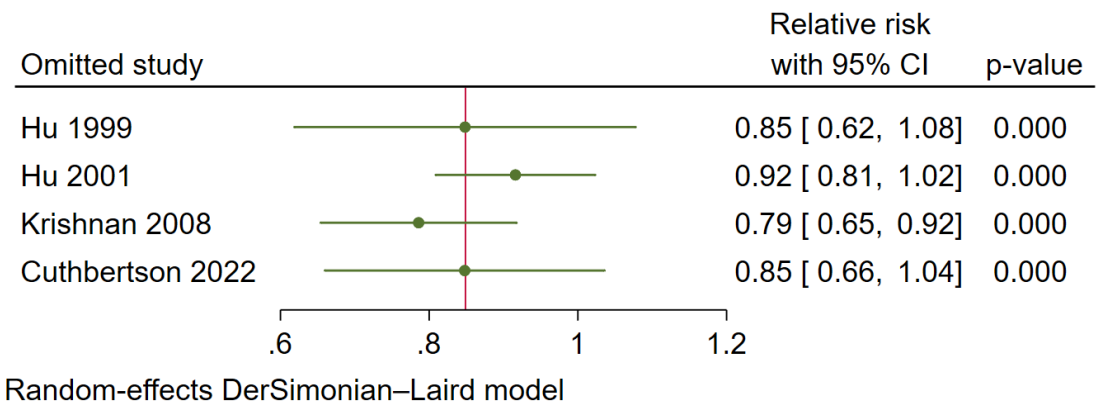
a. Downgraded twice since all studies judged as serious risk of bias based on ROBINS-I were included in the meta-analysis and residual confounding cannot be ruled out.
b. Serious inconsistency since I^2 = 70%. Downgraded.
c. Serious imprecision since the point estimate of the absolute effect was lower than 2%, and 95%CI included null value. Downgraded.
d. Downgraded twice since 8 studies with high weighting (81%) judged as serious risk of bias based on ROBINS-I were included in the meta-analysis and residual confounding cannot be ruled out.
e. Serious inconsistency since I^2=88%; however, a pre-specified subgroup analysis by method of walking speed assessment explained the observed heterogeneity. Not downgraded.
f. Serious imprecision since the point estimate of the absolute effect was lower than 2%. Downgraded.
g. Downgraded twice since 5 studies with high weighting (89%) judged as serious risk of bias based on ROBINS-I were included in the meta-analysis and residual confounding cannot be ruled out.
h. Serious inconsistency since I^2=81%; however, 6 out of 7 studies were in the same direction and reported consistent inverse association, and a pre-specified influence analysis explained most of the observed heterogeneity (RR after exclusion of the Kaplan et al. was 0.57, 95%CI: 0.46, 0.69; I^2=12%). Not downgraded.
i. Not serious since the point estimate in the absolute effect surpassed the MID threshold. Not downgraded.



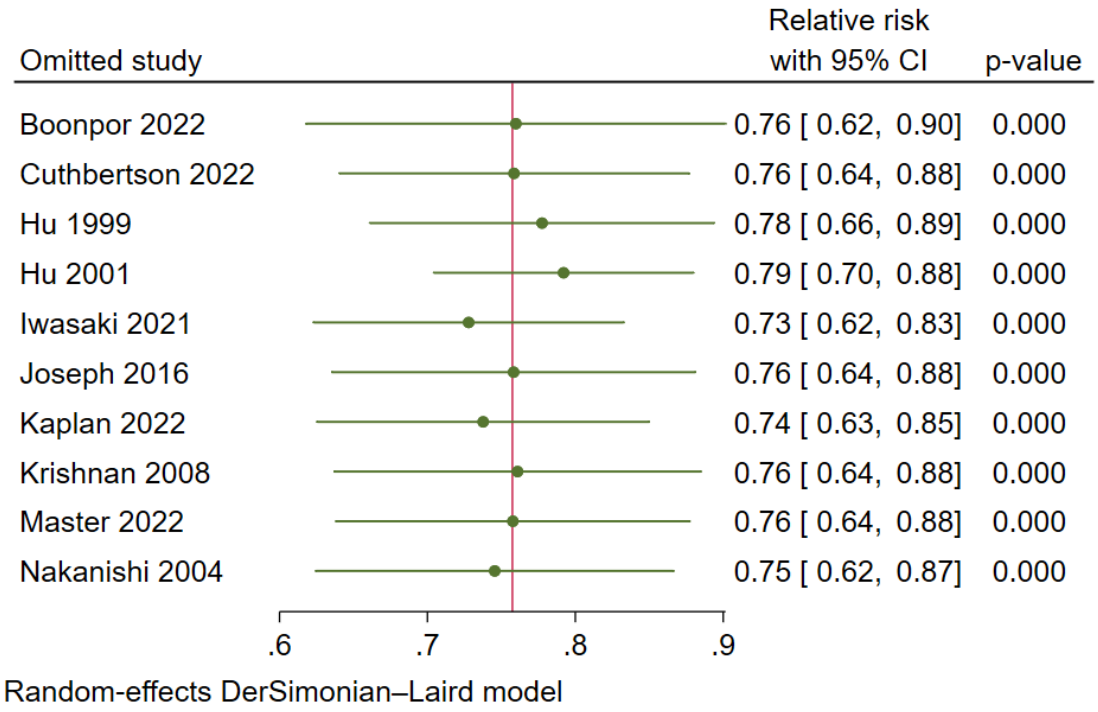
eFigure 1. Literature search and study selection process.



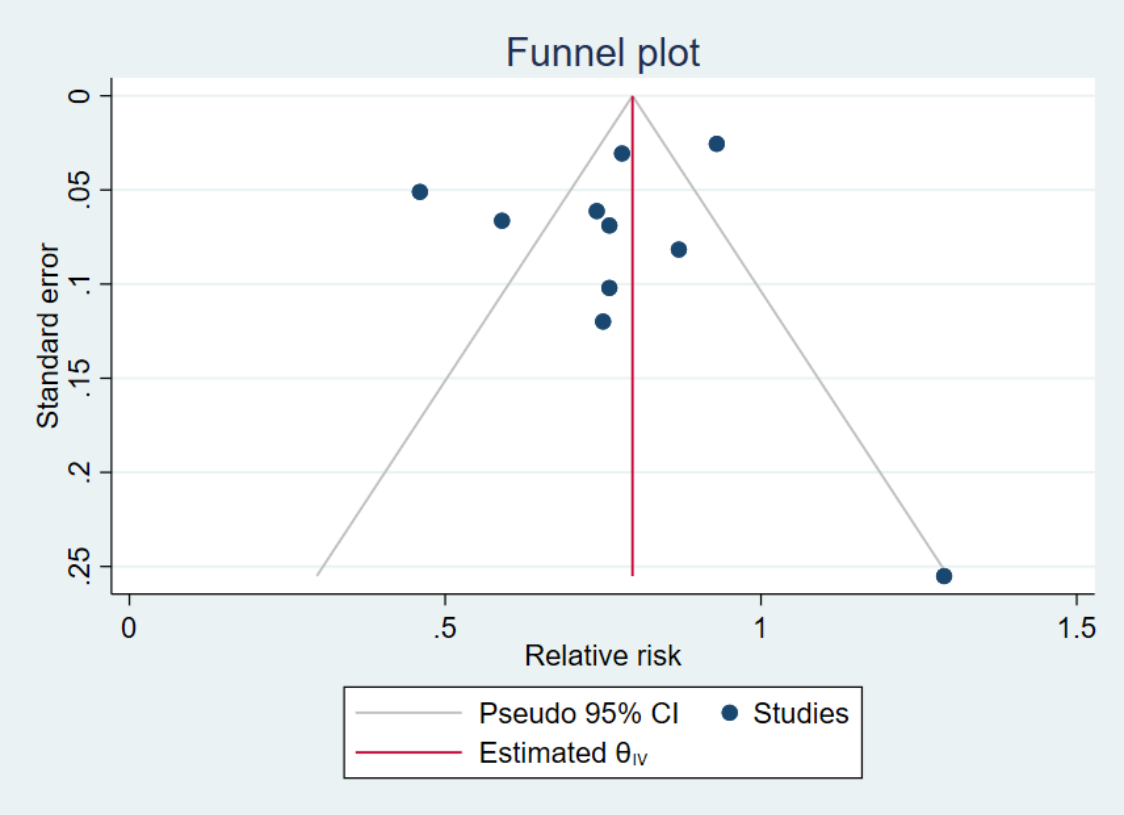
eFigure 2. Relative risk of type 2 diabetes for average/normal walking.



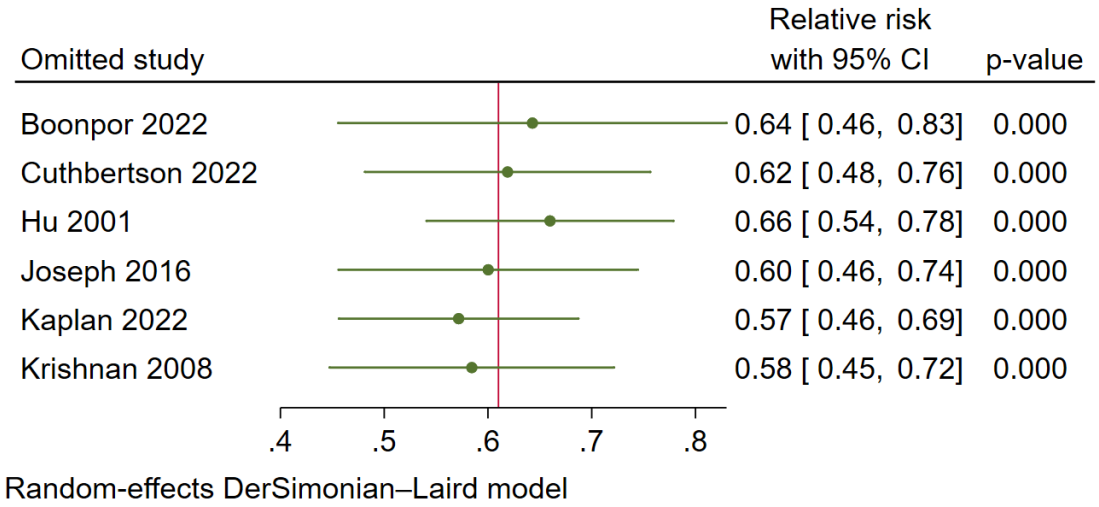
eFigure 3. Influence analysis showing the relative risk of type 2 diabetes for average/normal walking after exclusion of every single study at a time.



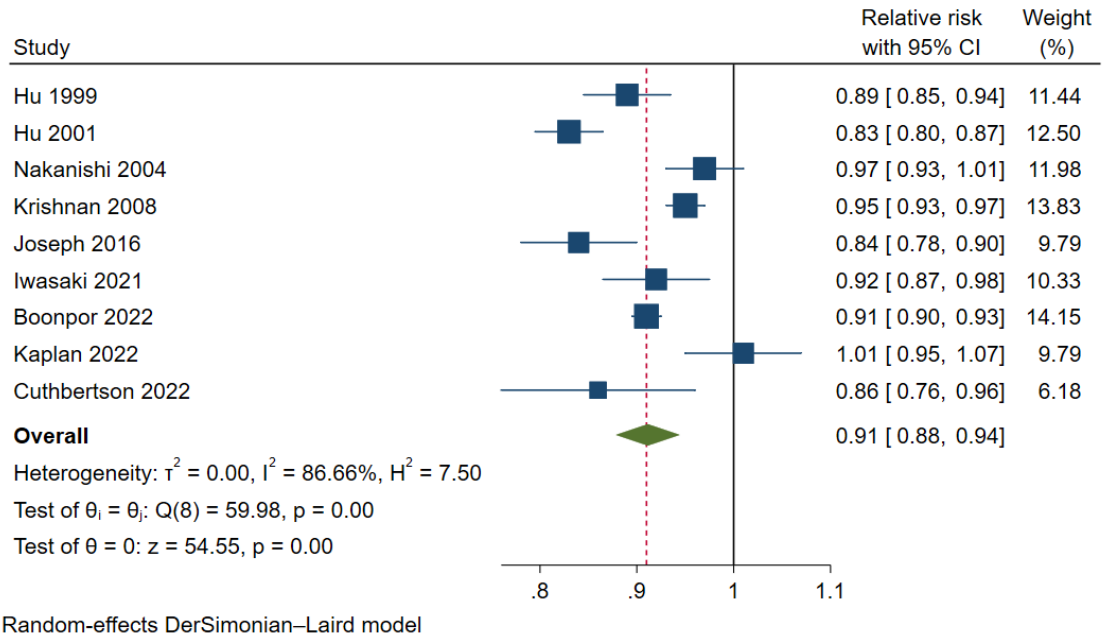
eFigure 4. Influence analysis showing the relative risk of type 2 diabetes for fairly brisk walking after exclusion of every single study at a time.



eFigure 5. Funnel plot of 10 cohort studies of the association between fairly brisk walking and the risk of type 2 diabetes.



eFigure 6. Influence analysis showing the relative risk of type 2 diabetes for brisk/striding walking after exclusion of every single study at a time.



eFigure 7. Relative risk of type 2 diabetes for each 1 km/hour increase in walking speed.

References:

1. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *Bmj* 2008;336:924-26
2. Morgan RL, Thayer KA, Santesso N, et al. A risk of bias instrument for non-randomized studies of exposures: a users' guide to its application in the context of GRADE. *Environment international* 2019;122:168-84
3. Schünemann HJ, Cuello C, Akl EA, et al. GRADE guidelines: 18. How ROBINS-I and other tools to assess risk of bias in nonrandomized studies should be used to rate the certainty of a body of evidence. *Journal of clinical epidemiology* 2019;111:105-14
4. Guyatt G, Oxman AD, Akl EA, et al. GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. *Journal of clinical epidemiology* 2011;64:383-94
5. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *bmj* 2016;355
6. Guyatt GH, Oxman AD, Kunz R, et al. GRADE guidelines: 7. Rating the quality of evidence—inconsistency. *Journal of clinical epidemiology* 2011;64:1294-302
7. Guyatt GH, Oxman AD, Kunz R, et al. GRADE guidelines: 8. Rating the quality of evidence—indirectness. *Journal of clinical epidemiology* 2011;64:1303-10
8. Guyatt GH, Oxman AD, Kunz R, et al. GRADE guidelines 6. Rating the quality of evidence—imprecision. *Journal of clinical epidemiology* 2011;64:1283-93
9. Johnston BC, Zeraatkar D, Steen J, et al. Saturated fat and human health: a protocol for a methodologically innovative systematic review and meta-analysis to inform public health nutrition guidelines. *Systematic Reviews* 2023;12:1-8
10. Hultcrantz M, Rind D, Akl EA, et al. The GRADE Working Group clarifies the construct of certainty of evidence. *Journal of clinical epidemiology* 2017;87:4-13
11. Zeng L, Brignardello-Petersen R, Hultcrantz M, et al. GRADE guidelines 32: GRADE offers guidance on choosing targets of GRADE certainty of evidence ratings. *Journal of Clinical Epidemiology* 2021;137:163-75
12. Smeeth L, Haines A, Ebrahim S. Numbers needed to treat derived from meta-analyses—sometimes informative, usually misleading. *Bmj* 1999;318:1548-51
13. Guyatt GH, Oxman AD, Montori V, et al. GRADE guidelines: 5. Rating the quality of evidence—publication bias. *Journal of clinical epidemiology* 2011;64:1277-82
14. Ballin M, Nordström P, Niklasson J, et al. Daily step count and incident diabetes in community-dwelling 70-year-olds: a prospective cohort study. *BMC Public Health* 2020;20:1-10
15. Bonora E, Kiechl S, Willeit J, et al. Population-based incidence rates and risk factors for type 2 diabetes in white individuals: the Bruneck study. *Diabetes* 2004;53:1782-89
16. Burchfiel CM, Sharp DS, Curb JD, et al. Physical activity and incidence of diabetes: the Honolulu Heart Program. *American journal of epidemiology* 1995;141:360-68
17. Burke V, Zhao Y, Lee AH, et al. Predictors of type 2 diabetes and diabetes-related hospitalisation in an Australian Aboriginal cohort. *Diabetes research and clinical practice* 2007;78:360-68
18. Carlsson S, Midthjell K, Tesfamarian M, et al. Age, overweight and physical inactivity increase the risk of latent autoimmune diabetes in adults: results from the Nord-Trøndelag health study. *Diabetologia* 2007;50:55-58
19. Chien K-L, Chen M-F, Hsu H-C, et al. Sports activity and risk of type 2 diabetes in Chinese. *Diabetes research and clinical practice* 2009;84:311-18
20. Demakakos P, Hamer M, Stamatakis E, et al. Low-intensity physical activity is associated with reduced risk of incident type 2 diabetes in older adults: evidence from the English Longitudinal Study of Ageing. *Diabetologia* 2010;53:1877-85

21. Dotevall A, Johansson S, Wilhelmsen L, et al. Increased levels of triglycerides, BMI and blood pressure and low physical activity increase the risk of diabetes in Swedish women. A prospective 18-year follow-up of the BEDA* study. *Diabetic Medicine* 2004;21:615-22
22. Engberg S, Glümer C, Witte DR, et al. Differential relationship between physical activity and progression to diabetes by glucose tolerance status: the Inter99 Study. *Diabetologia* 2010;53:70-78
23. Fan S, Chen J, Huang J, et al. Physical activity level and incident type 2 diabetes among Chinese adults. *Medicine and science in sports and exercise* 2015;47:751-56
24. Folsom AR, Kushi LH, Hong C-P. Physical activity and incident diabetes mellitus in postmenopausal women. *American Journal of Public Health* 2000;90:134
25. Fossum E, Gleim G, Kjeldsen SE, et al. The effect of baseline physical activity on cardiovascular outcomes and new-onset diabetes in patients treated for hypertension and left ventricular hypertrophy: the LIFE study. *Journal of internal medicine* 2007;262:439-48
26. Fretts AM, Howard BV, Kriska AM, et al. Physical activity and incident diabetes in American Indians: the Strong Heart Study. *American journal of epidemiology* 2009;170:632-39
27. Grøntved A, Pan A, Mekary RA, et al. Muscle-strengthening and conditioning activities and risk of type 2 diabetes: a prospective study in two cohorts of US women. *PLoS medicine* 2014;11:e1001587
28. Haapanen N, Miilunpalo S, Vuori I, et al. Association of leisure time physical activity with the risk of coronary heart disease, hypertension and diabetes in middle-aged men and women. *International journal of epidemiology* 1997;26:739-47
29. Helmrich SP, Ragland DR, Leung RW, et al. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. *New England journal of medicine* 1991;325:147-52
30. Hsia J, Wu L, Allen C, et al. Physical activity and diabetes risk in postmenopausal women. *American journal of preventive medicine* 2005;28:19-25
31. Huai P, Han H, Reilly KH, et al. Leisure-time physical activity and risk of type 2 diabetes: a meta-analysis of prospective cohort studies. *Endocrine* 2016;52:226-30
32. Jefferis BJ, Whincup PH, Lennon L, et al. Longitudinal associations between changes in physical activity and onset of type 2 diabetes in older British men: the influence of adiposity. *Diabetes care* 2012;35:1876-83
33. Jonker JT, De Laet C, Franco OH, et al. Physical activity and life expectancy with and without diabetes: life table analysis of the Framingham Heart Study. *Diabetes care* 2006;29:38-43
34. Katzmarzyk P, Craig C, Gauvin L. Adiposity, physical fitness and incident diabetes: the physical activity longitudinal study. *Diabetologia* 2007;50:538-44
35. Kraus WE, Yates T, Tuomilehto J, et al. Relationship between baseline physical activity assessed by pedometer count and new-onset diabetes in the NAVIGATOR trial. *BMJ Open Diabetes Research and Care* 2018;6:e000523
36. Kriska AM, Saremi A, Hanson RL, et al. Physical activity, obesity, and the incidence of type 2 diabetes in a high-risk population. *American journal of epidemiology* 2003;158:669-75
37. Kumari M, Head J, Marmot M. Prospective study of social and other risk factors for incidence of type 2 diabetes in the Whitehall II study. *Archives of internal medicine* 2004;164:1873-80
38. Laaksonen MA, Knekt P, Rissanen H, et al. The relative importance of modifiable potential risk factors of type 2 diabetes: a meta-analysis of two cohorts. *European journal of epidemiology* 2010;25:115-24
39. Lecomte P, Caces E, Born C, et al. Five-year predictive factors of type 2 diabetes in men with impaired fasting glucose. *Diabetes & metabolism* 2007;33:140-47
40. Lee D-c, Park I, Jun T-W, et al. Physical activity and body mass index and their associations with the development of type 2 diabetes in Korean men. *American journal of epidemiology* 2012;176:43-51

41. Longo-Mbenza B, Kasiam Lasi On'kin J, Nge Okwe A, et al. Metabolic syndrome, aging, physical inactivity, and incidence of type 2 diabetes in general African population. *Diabetes and Vascular Disease Research* 2010;7:28-39
42. Lynch J, Helmrich SP, Lakka TA, et al. Moderately intense physical activities and high levels of cardiorespiratory fitness reduce the risk of non-insulin-dependent diabetes mellitus in middle-aged men. *Archives of internal medicine* 1996;156:1307-14
43. Manson JE, Stampfer M, Colditz G, et al. Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *The Lancet* 1991;338:774-78
44. Mehlig K, Skoog I, Waern M, et al. Physical activity, weight status, diabetes and dementia: a 34-year follow-up of the population study of women in Gothenburg. *Neuroepidemiology* 2014;42:252-59
45. Meisinger C, Löwel H, Thorand B, et al. Leisure time physical activity and the risk of type 2 diabetes in men and women from the general population: the MONICA/KORA Augsburg Cohort Study. *Diabetologia* 2005;48:27-34
46. Monterrosa AE, Haffner SM, Stern MP, et al. Sex difference in lifestyle factors predictive of diabetes in Mexican-Americans. *Diabetes care* 1995;18:448-56
47. Mozaffarian D, Kamineni A, Carnethon M, et al. Lifestyle risk factors and new-onset diabetes mellitus in older adults: the cardiovascular health study. *Archives of internal medicine* 2009;169:798-807
48. Nilsson PM, Rööst M, Engström G, et al. Incidence of diabetes in middle-aged men is related to sleep disturbances. *Diabetes care* 2004;27:2464-69
49. Njølstad I, Amesen E, Lund-Larsen P. Sex differences in risk factors for clinical diabetes mellitus in a general population: a 12-year follow-up of the Finnmark Study. *American journal of Epidemiology* 1998;147:49-58
50. Okada K, Hayashi T, Tsumura K, et al. Leisure-time physical activity at weekends and the risk of Type 2 diabetes mellitus in Japanese men: the Osaka Health Survey. *Diabetic Medicine* 2000;17:53-58
51. Onat A, Hergenē G, Küēükdurmaz Z, et al. Prospective evidence for physical activity protecting Turkish adults from metabolic disorders. *Archives of the Turkish Society of Cardiology* 2007;35:467-74
52. Patja K, Jousilahti P, Hu G, et al. Effects of smoking, obesity and physical activity on the risk of type 2 diabetes in middle-aged Finnish men and women. *Journal of internal medicine* 2005;258:356-62
53. Perry AS, Annis JS, Master H, et al. Association of Longitudinal Activity Measures and Diabetes Risk: An Analysis From the National Institutes of Health All of Us Research Program. *The Journal of Clinical Endocrinology & Metabolism* 2023;108:1101-09
54. Ponsonby A-L, Sun C, Ukoumunne OC, et al. Objectively measured physical activity and the subsequent risk of incident dysglycemia: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes care* 2011;34:1497-502
55. Qiu S, Cai X, Zheng P, et al. Changes in objectively-measured physical capability over 4-year, risk of diabetes, and glycemic control in older adults: The China Health and Retirement Longitudinal study. *Diabetes Research and Clinical Practice* 2022;184:109186
56. Radford NB, DeFina LF, Barlow CE, et al. Effect of fitness on incident diabetes from statin use in primary prevention. *Atherosclerosis* 2015;239:43-49
57. Rana JS, Li TY, Manson JE, et al. Adiposity compared with physical inactivity and risk of type 2 diabetes in women. *Diabetes care* 2007;30:53-58
58. Rathmann W, Strassburger K, Heier M, et al. Incidence of Type 2 diabetes in the elderly German population and the effect of clinical and lifestyle risk factors: KORA S4/F4 cohort study. *Diabetic Medicine* 2009;26:1212-19
59. Sato KK, Hayashi T, Kambe H, et al. Walking to work is an independent predictor of incidence of type 2 diabetes in Japanese men: the Kansai Healthcare Study. *Diabetes Care* 2007;30:2296-98
60. Schulze MB, Hoffmann K, Boeing H, et al. An accurate risk score based on anthropometric, dietary, and lifestyle factors to predict the development of type 2 diabetes. *Diabetes care* 2007;30:510-15

61. Shi L, Shu X-O, Li H, et al. Physical activity, smoking, and alcohol consumption in association with incidence of type 2 diabetes among middle-aged and elderly Chinese men. *PloS one* 2013;8:e77919
62. Siegel LC, Sesso HD, Bowman TS, et al. Physical activity, body mass index, and diabetes risk in men: a prospective study. *The American journal of medicine* 2009;122:1115-21
63. Sieverdes JC, Sui X, Lee D-c, et al. Physical activity, cardiorespiratory fitness and the incidence of type 2 diabetes in a prospective study of men. *British journal of sports medicine* 2010;44:238-44
64. Simonsick EM, Lafferty ME, Phillips CL, et al. Risk due to inactivity in physically capable older adults. *American Journal of Public Health* 1993;83:1443-50
65. Steinbrecher A, Erber E, Grandinetti A, et al. Physical activity and risk of type 2 diabetes among Native Hawaiians, Japanese Americans, and Caucasians: the Multiethnic Cohort. *Journal of Physical Activity and Health* 2012;9:634-41
66. Sui X, Hooker SP, Lee I-M, et al. A prospective study of cardiorespiratory fitness and risk of type 2 diabetes in women. *Diabetes care* 2008;31:550-55
67. uk ICUem-eca. Physical activity reduces the risk of incident type 2 diabetes in general and in abdominally lean and obese men and women: the EPIC–InterAct Study. *Diabetologia* 2012;55:1944-52
68. Villegas R, Shu X-O, Li H, et al. Physical activity and the incidence of type 2 diabetes in the Shanghai women's health study. *International journal of epidemiology* 2006;35:1553-62
69. Waki K, Noda M, Sasaki S, et al. Alcohol consumption and other risk factors for self-reported diabetes among middle-aged Japanese: a population-based prospective study in the JPHC study cohort I. *Diabetic medicine* 2005;22:323-31
70. Waller K, Kaprio J, Lehtovirta M, et al. Leisure-time physical activity and type 2 diabetes during a 28 year follow-up in twins. *Diabetologia* 2010;53:2531-37
71. Wannamethee SG, Shaper AG, Alberti KGM. Physical activity, metabolic factors, and the incidence of coronary heart disease and type 2 diabetes. *Archives of Internal Medicine* 2000;160:2108-16
72. Weinstein AR, Sesso HD, Lee IM, et al. Relationship of physical activity vs body mass index with type 2 diabetes in women. *Jama* 2004;292:1188-94
73. Williams PT, Thompson PD. Walking versus running for hypertension, cholesterol, and diabetes mellitus risk reduction. *Arteriosclerosis, thrombosis, and vascular biology* 2013;33:1085-91
74. Xu F, Wang Y, Ware RS, et al. Physical activity, family history of diabetes and risk of developing hyperglycaemia and diabetes among adults in Mainland China. *Diabetic medicine* 2012;29:593-99
75. Aune D, Norat T, Leitzmann M, et al. Physical activity and the risk of type 2 diabetes: a systematic review and dose–response meta-analysis. *European journal of epidemiology* 2015;30:529-42
76. Hamer M, Chida Y. Walking and primary prevention: a meta-analysis of prospective cohort studies. *British journal of sports medicine* 2008;42:238-43
77. Liu B, Hu X, Zhang Q, et al. Usual walking speed and all-cause mortality risk in older people: A systematic review and meta-analysis. *Gait & posture* 2016;44:172-77
78. Perera S, Patel KV, Rosano C, et al. Gait speed predicts incident disability: a pooled analysis. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences* 2016;71:63-71
79. Quan M, Xun P, Wang R, et al. Walking pace and the risk of stroke: a meta-analysis of prospective cohort studies. *Journal of Sport and Health Science* 2020;9:521-29
80. Stamatakis E, Kelly P, Strain T, et al. Self-rated walking pace and all-cause, cardiovascular disease and cancer mortality: individual participant pooled analysis of 50 225 walkers from 11 population British cohorts. *British Journal of Sports Medicine* 2018;52:761-68
81. Veronese N, Stubbs B, Volpato S, et al. Association between gait speed with mortality, cardiovascular disease and cancer: a systematic review and meta-analysis of prospective cohort studies. *Journal of the American Medical Directors Association* 2018;19:981-88. e7

82. Hall KS, Hyde ET, Bassett DR, et al. Systematic review of the prospective association of daily step counts with risk of mortality, cardiovascular disease, and dysglycemia. *International Journal of Behavioral Nutrition and Physical Activity* 2020;17:1-14
83. Ishizaki T, Kobayashi E, Fukaya T, et al. Association of physical performance and self-rated health with multimorbidity among older adults: results from a nationwide survey in Japan. *Archives of Gerontology and Geriatrics* 2019;84:103904
84. Rosano C, Newman AB, Katz R, et al. Association between lower digit symbol substitution test score and slower gait and greater risk of mortality and of developing incident disability in well-functioning older adults. *Journal of the American Geriatrics Society* 2008;56:1618-25
85. Boonpor J, Parra-Soto S, Gore J, et al. Association Between Walking Pace and Incident Type 2 Diabetes by Adiposity Levels–A Prospective Cohort Study from The UK Biobank. *Diabetes, Obesity and Metabolism* 2023;
86. Cigarroa I, Bravo-Leal M, Petermann-Rocha F, et al. Brisk walking pace is associated with better cardiometabolic health in adults: findings from the Chilean national health survey 2016–2017. *International Journal of Environmental Research and Public Health* 2023;20:5490
87. Alenazi AM, Alqahtani BA, Vennu V, et al. Gait speed as a predictor for diabetes incidence in people with or at risk of knee osteoarthritis: a longitudinal analysis from the osteoarthritis initiative. *International Journal of Environmental Research and Public Health* 2021;18:4414