BMC Musculoskeletal Disorders

https://doi.org/10.1186/s12891-025-09358-5

Article in Press

Adolescent health behaviors, family socioeconomic status and health as risk factors for tendon ruptures in adulthood: a longitudinal study

Received: 14 May 2025

Accepted: 18 November 2025

Published online: 25 November 2025

Cite this article as: Teuho A., Vaajala M., Ponkilainen V. *et al.* Adolescent health behaviors, family socioeconomic status and health as risk factors for tendon ruptures in adulthood: a longitudinal study. *BMC Musculoskelet Disord* (2025). https://doi.org/10.1186/s12891-025-09358-5

Alisa Teuho, Matias Vaajala, Ville Ponkilainen, Leena Koivusilta, Arja Rimpelä & Ville M. Mattila

Adolescent health behaviors, family socioeconomic status and health as risk factors for tendon ruptures in adulthood: a longitudinal study

Alisa Teuho MD[1]; Matias Vaajala BM[1]; Ville Ponkilainen MD, PhD[2]; Leena Koivusilta PhD, MSc[3]; Arja Rimpelä MD, PhD[4, 5]; Ville M. Mattila MD, PhD[1, 2]

Affiliations:

[1] Faculty of Medicine and Life Sciences, University of Tampere, Tampere, Finland

[2]Department of Orthopedics and Traumatology, Tampere University Hospital, Tampere, Finland

[3]Department of Social Research, Faculty of Social Sciences, University of Turku, Turku, Finland

[4]Unit of Health Sciences, Faculty of Social Sciences, Tampere University, Tampere, Finland

[5]Department of Adolescent Psychiatry, Tampere University Hospital, Tampere, Finland

Corresponding author: Alisa Teuho

E-mail: alisa.teuho@tuni.fi

Abstract

Introduction

The incidence of tendon ruptures has increased in recent years highlighting the need of better understanding their causes and prevention strategies. This study aims to investigates the influence of adolescent health behaviors (smoking, alcohol use, physical activity), health (self-reported chronic disease, overweight), and family socioeconomic status (SES) (parental occupational status and educational level) on later tendon ruptures until middle age in Finnish adolescents.

Materials and methods

The baseline data were surveys gathered biennially in 1981-1997 (the Adolescent Health and Lifestyle Survey) and linked individually with diagnoses of tendon ruptures (Achilles, quadriceps, hamstring, biceps tendon, and rotator cuff) retrieved from the Care Register for Health Care. A logistic regression model was used to analyze the associations between adolescents' health behaviors, health and family socioeconomic status on later tendon rupture. Adjusted odds ratios (aOR) with 95% confidence intervals (CIs) were computed.

Results

Total of 42 971 persons were included in the analyses. The mean follow-up time was 25.2 years and during the follow-up 685 tendon ruptures occurred. Males were more likely to incur tendon rupture. The mean age at the time of tendon rupture was 36.6 years. Frequent activity in sports clubs increased the odds of tendon rupture (2 to 3 times a week or less aOR 1.73, CI 1.45-2.05, 4 or more times a week aOR 3.54, CI 2.88-4.32). The association was seen in both genders. Daily smoking, alcohol use, physical activity in leisure time, overweight, chronic disease, or parental socioeconomic status in adolescence were not associated with the risk of tendon rupture.

Conclusion

Frequent participation in physical activity in sports clubs during adolescence increases the risk of tendon rupture in adulthood while other physical activity in leisure time does not. Health compromising behaviors (smoking, alcohol use, overweight) or chronic diseases in adolescence does not seem to play a role in later tendon ruptures until middle age.

Keywords: tendon rupture, health behaviors, health, epidemiology

Clinical trial number: Not applicable.

Introduction

Tendon ruptures, including Achilles, quadriceps, hamstring, biceps and rotator cuff ruptures, are common in middle-aged individuals, typically between 40 and 50 years old (1–4). While all tendon ruptures share similar pathophysiological features, such as underlying degenerative changes, the mechanisms leading to these injuries vary (5–8). Quadriceps ruptures are commonly associated with falls (1,9), biceps ruptures with heavy lifting or falls (10), hamstring and rotator cuff ruptures with sports or falls (11,12), and Achilles ruptures with high-impact sports or sudden accelerations (13). Notably, the incidence of these tendon ruptures has increased in recent years (3,4,10,14,15), possibly due to more active lifestyle among ageing population (16). This highlights the need for a better understanding of their causes and prevention strategies.

As health and health behaviors starts forming in adolescence and both poorer health and health behaviors are an observed contributors of tendon degeneration in adults the existence of these factors in adolescence may cause early onset degeneration or predict the prevalence of these factors in adulthood. In studies on adults, several factors increase the risk of tendon rupture. Males have higher susceptibility of sustaining tendon rupture (3). Additionally, certain medications—anabolic steroids, quinolones, and corticosteroids—also used in the treatment of chronic diseases are associated with an increased risk of tendon rupture (17–19). For example, a study conducted in the UK reported oral cortisone to increase the risk of Achilles and biceps tendon rupture dose-dependently (5). Overweight has also been associated with Achilles and rotator cuff tendinopathy, as well as with increased risk of tendon ruptures (20). Moreover, health-compromising lifestyle factors, such as alcohol consumption and smoking, have been suggested to negatively affect tendon integrity and contribute to degenerative changes, thus increasing the risk of ruptures (19,21–26). However, the evidence on certain risk

factors is contradictory. Some studies have suggested type 2 diabetes as a risk factor for tendon ruptures (27,28) while the others have not found this association (2). Still, tendon degeneration in general has been related to chronic diseases in adults (1,29) but studies from the perspective of adolescence perspective are lacking. In contrast, certain tendon ruptures are commonly associated with sports involving high-impact load and rapid acceleration, in which the risk of falls and injuries is also increased. This further elevates the likelihood of these injuries. Extensive physical activity may also cause degeneration of tendons, due to excessive load and stress, and is reported among both recreational athletes and athletes (30). Overall, there is a lack of longitudinal studies examining how adolescent health and health behaviours influence the risk of tendon ruptures later in life.

Family SES affects the development of adolescent health behavior and health (31,32) and thus may predispose to future tendon ruptures. Among adults, the association of socioeconomic position with tendon rupture is not unambiguous. Individuals with higher socioeconomic status (SES) tend to present more Achilles ruptures (33). However, lower educational level is associated with rotator cuff tendinopathy (34). Health-compromising behaviours and poor health—which can negatively affect tendon structure—are more common among individuals with low socioeconomic status (35). Health compromising behaviours also contribute to an increased risk of injury (36). Further, as tendon ruptures are usually caused by the combination of injury and pre-existing degeneration, the risk factors are also diverse.

This study aims to investigate the influence of adolescent health behaviors (smoking, alcohol use, physical activity), health (self-reported chronic disease, overweight), and family SES (parental occupational status and educational level) on later tendon ruptures until middle age in a large cohort of Finnish adolescents.

Methods

Study design

In this longitudinal study, data from the Adolescent Health and Lifestyle Survey (AHLS) were individually combined with sociodemographic information sourced from Statistics Finland and outcome data obtained from the Care Register for Health Care. The follow-up endpoint for each participant was the first emergency department visit or hospital admission due to a rupture of Achilles, quadriceps, hamstring, biceps tendon, or rotator cuff, emigration, death, or the end of the follow-up on December 31, 2018.

Study population and baseline data

The baseline data were obtained from the AHLS (37). The surveys began in 1977 and were conducted every other year between February and March. Survey questionnaires were mailed to all 14, 16 or 18-year-old Finnish adolescents who were born on certain days in June, July or August and thus no seasonal bias exists in the studied cohort. Individual follow-up started on April 30 of the same year in which each participant completed their survey. Samples were drawn from the Population Register Centre. Non-respondents received two re-inquiries. In this study, data collected between 1981 and 1997 was used and if the adolescent had responded more than one survey only the primary survey was used. The baseline cohort consisted of 60 941 individuals from which 47 747 responded to the survey. The overall response rate was 78%, 71% in men and 86% in women. Individuals with missing answers in analyzed questions in the AHLS were excluded from the study (n= 4 776).

Explanatory variables

Variables representing health behaviors (smoking, alcohol use, physical activity) and health (overweight, chronic disease) were obtained from the AHLS and family SES (parental educational level and occupational status) from the national registries of Statistics Finland. The explanatory variables used, and the descriptions are presented in Table 1 and the frequencies of distributions in the answers in Supplementary table 1.

Table 1. Description of explanatory variables used in the analyses.

Variable and its source	Original variable and formation of the variable used in the analyses	Values
Daily use of tobacco, AHLS	Combining questions on tobacco experimentation and frequency of tobacco use	No = 1 Yes = 2
Alcohol use, AHLS	Question on frequency of alcohol use and drunkenness	Never drunk = 1 Drunk occasionally but not drunkenness = 2 Drunk once or twice a month but rarely drunkenness = 3 Drunk once a week or more often and drunkenness = 4
Frequency of physical activity in leisure time, AHLS	Question on frequency of leisure time physical activity	Never = 1 2 to 3 times a week or less = 2 4 or more times a week = 3
Frequency of physical activity in sports clubs, AHLS	Question on frequency of leisure time physical activity	Never = 1 2 to 3 times a week or less = 2 4 or more times a week = 3
Overweight, AHLS	BMI calculated from self-reported height (cm) and weight (kg)	No = 1 Yes = 2 (overweight according to Cole´s criteria) (38)
Self-reported chronic disease and disabilities, AHLS	Question on long-term disease or disability that disturbs your everyday life.	No = 1 Yes = 2
SES, parental educational level, Statistics Finland	Educational-based status of the respondent' mother and father from the national registries of Statistics Finland. The registry data on socioeconomic circumstances had been obtained from national censuses conducted every fifth year until 1995 and from on-line registry data on a yearly basis from 2000 onwards.	Both high = 1 Either one high = 2 Either one middle = 3 Both low = 4
SES, parental occupational status, Statistics Finland	Occupation-based status of the respondent' mother and father from the national registries of Statistics Finland. The registry data on socioeconomic circumstances had been obtained from national censuses conducted every fifth year until 1995 and from on-line registry data on a yearly basis from 2000 onwards. Classification of Statistics Finland.	Both parents' unknown = 0 Both parents upper white-collar = 1 Either one upper white-collar = 2 Either one lower white-collar = 3 Either one blue-collar = 4

Outcome variable

The outcome was an outpatient visit or hospitalization due to trauma-related degenerative tendon rupture. Only the primary diagnosis of the visit was included. Data on the outcome variables were obtained from the Care Register for Health Care, containing information on participants discharged from inpatient care, day surgeries, and specialized outpatient care. The coverage and quality of the Care Register for Health Care are good (39–41). Even though the first surveys ended in 1981 ICD-10 (International Classification of Diseases 10th revision) diagnoses of tendon ruptures were only used from the year 1997 for better data reliability, due to the change in the ICD-coding system. ICD-10 codes used were S46.0 injury of muscles and tendons of the rotator cuff of shoulder, S46.2 injury of muscle, fascia and tendon of the other parts of biceps, S76.1 injury of quadriceps muscle and tendon, S76.3 injury of muscles and tendons of the posterior muscle group at thigh level, and S86.0 injury of Achilles tendon.

Statistical methods

A multivariable logistic regression model was used to analyze the associations between explanatory variables and tendon ruptures. The results from the models were presented as adjusted odds ratios (aOR) with 95% confidence intervals (CIs) for explanatory variables. The models were created separately for females and males. Directed acyclic graphs (DAGs) were used to select the variables for adjusting the logistic regression models. The selection of the variables for the DAGs were made based on previously observed risk factors and hypothesized causal pathways. The models were constructed using the free online software DAGitty (dagitty.net) (Supplementary figures 1-7).(42) DAGitty proposes possible sets of adjustment variables that could influence the primary outcome and identifies the smallest set required to block all non-causal paths. This assures that none of the nodes in the set are descendants of the explanatory variable and that all backdoor paths are blocked when conditioning on this set. Algorithms from

graph theory and causal inference are used by the software to automate the process, also, generating real-time feedback on the adequacy of the adjustments.(43) Smoking was adjusted with alcohol use and parental occupational status whereas alcohol use was adjusted with smoking and parental occupational status. Physical activity in leisure time was adjusted with physical activity in sports clubs and way around. Overweight was adjusted with both types of physical activity and, lastly, chronic disease with overweight, smoking. and alcohol use. Statistical analyses were performed with R version 4.0.5 (R foundation for Statistical Computing, Vienna, Austria).

Results

Total of 42 971 persons were included in the analyses, of which 23 548 were females and 19 423 males. The mean follow-up time was 25.2 years and the mean age at the end of a follow up was 42.7 years. The mean age at the time of tendon rupture were 36.6 years (SD 6.6), in females 37.7 years (SD 7.2) and in males 36.2 years (SD 6.3). During the follow-up period, total of 685 tendon ruptures occurred. Males were more likely to experience tendon rupture (male 73.7% vs female 26.3%). The most common diagnoses were injury of rotator cuff tendon in females and injury of Achilles tendon in males. In total, 18.8% of tendon ruptures were treated surgically (female 14.4% vs male 20.4%). (Table 2 and 3)

Table 2. Background information for tendon ruptures by gender used in the analyses.

	Sample size, N (%)	**Tendon ruptures, N (%)**	**Mean follow-up time, years (standard deviation)**	**Mean age of tendon rupture, years (standard deviation)**	**Surgical treatment, N (%)**
Female	23 548 (54.8)	180 (26.3)	25.3 (4.0)	37.7 (7.2)	26 (20.2)
Male	19 423 (47.8)	505 (73.7)	25.1 (4.4)	36.2 (6.3)	103 (79.8)
All	42 971 (100)	685 (100)	25.2 (4.2)	36.6 (6.6)	129 (100)

Table 3. Number of tendon ruptures during the follow-up with ICD-10 codes.

ICD-10 codes	Male	Female	All
S46. 0 Injury of muscles and tendons of the rotator cuff of shoulder	173	97	270
S46.2 Injury of muscle, fascia and tendon of other parts of biceps	46	4	50
S76.1 Injury of quadriceps muscle and tendon	27	3	30
S76.3 Injury of muscles and tendons of the posterior muscle group at thigh level	20	25	45
S86.0 Injury of Achilles tendon	239	51	290
	505	**180**	**685**

In the logistic regression analysis, frequent participation in physical activity in sports clubs increased the odds of tendon rupture in both genders (2 to 3 times a week or less aOR = 1.73, 95% CI 1.45-2.05, 4 or more times a week aOR = 3.54, 95% CI 2.88-4.32) compared to those who never participated in sports club activity. An increase in the risk was seen separately in females (4 or more times a week aOR = 2.98, 95% CI 1.87-4.58) and males (2 to 3 times a week or less aOR = 1.67, 95% CI 1.35-2.05; 4 or more times a week aOR = 2.69, 95% CI 2.23-3.39), too. We found no relationship between in daily smoking, alcohol use, physical activity in leisure time, overweight, chronic disease, or parental socioeconomic status and the likelihood of tendon rupture. (Table 4)

Table 4. Adjusted odds ratios (aOR) with 95 % confidence intervals (CI) for tendon ruptures by gender.

	All		Female		Male	
	aOR	95% CI	aOR	95% CI	aOR	95% CI
Daily use of tobacco [a]						
No	1.00		1.00		1.00	
Yes	1.15	0.95-1.38	1.11	0.76-1.60	1.14	0.92-1.42
Alcohol use [b]						
Abstinence or occasional	1.00		1.00		1.00	
Drunk once or more a month	1.01	0.82-1.24	0.85	0.54-1.30	0.92	0.73-1.16
Physical activity leisure time [c]						
Never	1.00		1.00		1.00	
2 to 3 times a week or less	0.97	0.67-1.47	0.80	0.41-1.78	1.21	0.78-2.01
4 or more times a week	1.17	0.79-1.80	0.97	0.48-2.23	1.40	0.86-2.36
Physical activity in sports clubs [d]						
Never	1.00		1.00		1.00	
2 to 3 times a week or less	1.73	1.45-2.05	1.29	0.93-1.79	1.67	1.35-2.05
4 or more times a week	3.54	2.88-4.32	2.98	1.87-4.58	2.69	2.23-3.39
Overweight [e]						
No	1.00		1.00		1.00	
Yes	1.26	0.99-1.58	0.80	0.41-1.40	1.15	0.89-1.47
Chronic disease or disability [f]						
No	1.00		1.00		1.00	
Yes	1.20	0.94.1.53	1.39	0.87-2.11	1.21	0.89-1.60
Parental educational level						
Both high	1.00		1.00		1.00	
Either one high	0.94	0.63-1.44	0.65	0.26-1.67	1.03	0.65-1.67

Either one middle	1.11	0.79-1.61	1.22	0.63-2.72	1.10	0.75-1.69
Both low	1.21	0.84-1.78	1.48	0.74-3.39	1.16	0.77-1.83
Parental occupational status						
Both upper white collar	1.00		1.00		1.00	
Either one upper white collar	0.87	0.69-1.09	0.99	0.63-1.60	0.85	0.65-1.10
Either one lower white collar	0.85	0.68-1.06	0.95	0.61-1.51	0.82	0.64-1.06
Either one blue collar	0.78	0.61-0.99	1.09	0.60-1.76	0.72	0.54-0.95
Both unknown	0.68	0.44-1.01	0.66	0.25-1.48	0.70	0.42-1.10

a Adjusted by alcohol use and parental occupational status

b Adjusted by smoking status and parental occupational status

c Adjusted by physical activity in sports clubs

d Adjusted by physical activity in leisure time

e Adjusted by physical activity in leisure time and sports clubs

f Adjusted by overweight, alcohol use, and smoking status

Discussion

The main finding was the positive association between frequent physical activity in sports clubs in adolescence and the risk of tendon rupture in later life. However, there was no association between physical activity in leisure time and the tendon rupture. The risk of tendon ruptures was not related to health compromising behaviors (smoking, alcohol use, overweight) or chronic disease in adolescence in spite that these are potential causes of tendon degeneration.

The observed association between physical activity in sports clubs and increased risk of tendon rupture complies to previous studies as tendon ruptures are linked to sports (4,44). When analyzing the genders separately males were more likely to sustain tendon ruptures, consistent with prior studies (2,44). In general, males are known to have higher susceptibility to injuries (45). Also, the participation in contacts sports—football, ice hockey—might be higher compared to females. However, the risk associated with higher physical activity in sports clubs was observed with similar effects sizes in both genders. Although the continuation of physical activity into adulthood could not be assessed due to the nature of the data, previous studies have shown that an active lifestyle in adolescence persists into adulthood, supporting our findings (46). Interestingly, we could not detect a similar relationship with leisure time physical activity and risk of tendon rupture. However, leisure time physical activity can include e.g. walking, jogging, gym workouts, or less intense exercises where the risk of injury and strain on tendons is minor. Compared to leisure time physical activity, activity in sports clubs causes more strain on tendons, as the training is more goal-oriented and demanding. In addition, physical activity in contact sports, e.g. football, exposes to high-risk events increasing the risk of injury. (47) Active participation in specific sport may cause narrowing in training and predispose to injuries as sport specific repetitive movements cause overuse and unfavorable stress on tendons (48,49). As a

continuation, more rotator cuff tears are seen in sports with repetitive overhead movements such as throwing (50).

Extensive training loads and overuse of tendons are associated with an increased risk of injury in both recreational athletes and competitive athletes (30). On the other hand, also less exercise may expose to tendon injuries when individuals are exposed to a sudden spike in physical strain, as the frequency or the load suddenly increases without the adaptation to more intensive training (51), which, however, may be a more present issue in recreational athletes. Mechanic chronic overuse and strain of tendons affects the health and structures of tendons causing pathological changes. Reactive oxygen species (ROS) and inflammation caused by executive stress is suggested to cause degeneration in tendons related to sports. (52) As mentioned above, narrowing and unbalance in training may expose to tendon injuries via sports related degeneration. Still, in general, the effects of regular exercise are beneficial and strengthens muscle strength and mobility.

Our observation of the lacking connection between factors known to cause degeneration in tendons and the risk of tendon injury partly differs from previous studies. As in earlier studies, smoking, chronic diseases, and obesity have been associated with tendon ruptures (2,20,27). Chronic inflammation and metabolic changes caused by chronic diseases and obesity presents in microscopic structural changes and fatty accumulation in tendons, which weakens and further predisposes to ruptures (21,53). However, the mean age at the time of injury or the age of the studied population has been higher in some of these studies and our risk factors were measured in adolescence and may have changed during the follow-up. Conversely, sedentary lifestyle as a protective factor for tendon injuries, especially for Achilles ruptures, via decreased physical activity, have been discussed too (54). As a conclusion, these health compromising factors inducing

tendon degeneration do not seem to play a significant role in tendon injuries until middle age when measured in adolescence (55).

A strength of this study lies in the large sample comprehensively presenting Finnish adolescents with a long follow up, 25 years on average. This study also poses its limitations. In addition to 22% of non-respondents 4 776 participants were excluded from the analyses due to missing answers in the surveys this may induce bias in the results if the excluded individuals differ systematically from those included. While this could slightly reduce the generalizability of the findings, the large remaining sample ensures the overall robustness and reliability of the results. In addition, all the variables describing health behavior and health were self-reported, however, previous research supports the reliability of self-reported data in similar contexts (56,57). Furthermore, we do not know how these characteristics and exposures measured in the adolescence changed over time. Due to age of the data, the generalizability of the findings to adolescents in the 21st century may be limited as the societal norms and environmental factors change over time, however differences in risk taking and health behaviors are still observed among adolescents today. Lastly, this data did not include information of the exact sports practiced, which could have provided information on the effects and risks of different sports. In future studies, analyzing also the effect of different sports on tendon ruptures would provide more comprehensive knowledge on the subject.

Conclusion

Frequent participation in physical activity in sports clubs during adolescence increases the risk of tendon rupture in adulthood while other physical activity in leisure time does not. Health compromising behaviors (smoking, alcohol use, overweight) or chronic diseases in adolescence does not seem to play a role in later tendon ruptures until middle age. More attention should be allocated to the prevention of overuse injuries,

particularly in sports clubs, among young and early middle-aged adults and to support versatile sports activity.

Abbreviations

SES Socioeconomic status

AHLS Adolescent Health and Lifestyle Survey

ICD-10 International Classification of Diseases 10th revision

aOR Adjusted odds ratio

CI Confidence interval

SD Standard deviation

DAG Directed acyclic graph

Declarations

Ethics approval and consent to participate

The Finnish Social and Health Data Permit Authority Finland granted the permit to use social and health care data (https://findata.fi) and linked that data with the data set of the Adolescent Health and Lifestyle Survey, measured biennially from 1981 to 1997. Statistics Finland linked these data sets. The study protocol was approved by its Institutional Review Board and by the Data Protection Ombudsman. Identification of the study participants was withheld from the investigators at all stages of the study and the rights and duties of both parties were specified in the contract. The Joint Commission on Ethics of the University of Turku and the Turku University Hospital stated that no human rights were violated in the research protocol and approved it. Parental consent was neither considered by the ethics review boards at that time nor was it needed for linking the data sets. When the permission to use register data was granted, the authorities were obliged to guarantee that the conditions described in the Personal Data Protection Act (523/1999) were followed (https://www.finlex.fi/fi/laki/alkup/1999/19990523).

The Adolescent Health and Lifestyle Survey data were gathered from 1981 to 1997, at the time when there was no specific legislation or national guidelines on parental consent. The first review boards at the universities were established in Finland in the 1980s. AHLS was reviewed by the Ethical Review Board of the University of Helsinki, Department of Public Health in 1986 but parental consent was not considered at that time. The purpose of the study was stated on the first page of the questionnaire or in a separate information letter. Participants' informed consent was shown by their answer to the survey. The questionnaires did not include questions that involve a risk of causing mental harm that exceeds the limits of normal daily life to the research participants. It was stated that if parents would like to get to know the questionnaire,

they were advised to do it before the adolescent answered. In later surveys of the Adolescent Health and Lifestyle Survey, the review boards waived parental consent, which is in line with the present national guidelines on ethical review in human sciences by the Finnish National Board on Research Integrity https://tenk.fi/en/ethical-review/ethical-review-human-sciences. Consequently, consent to participate wasn't obtained from parents or legal guardians, as there was no specific legislation on the subject. Also, later the review boards waived parental consent.

Consent for publication

Not applicable.

Availability of data and materials

Due to existing Finnish data legislation, sharing the data is not possible.

Competing Interests

The authors declare that they have no financial or non-financial interests.

Funding

This study was financially supported by Juho Vainio Foundation (8 Dec 2021) and the state funding for university level health research, Tampere University Hospital, Wellbeing Services County of Pirkanmaa (9X048, 9AB061).

Author Contributions

AT, MV, VP, LK, AR and VM conceptualized the study. AT and MV planned the methodology. AT carried out the statistical analyses. AT and MV wrote the first draft of the manuscript. All authors commented and edited the text. Final manuscript was approved by all authors.

Acknowledgements

None.

References

1. Arnold EP, Sedgewick JA, Wortman RJ, Stamm MA, Mulcahey MK. Acute Quadriceps Tendon Rupture: Presentation, Diagnosis, and Management. JBJS Reviews. 2022 Feb;10(2):e21.00171.
2. Kelly MP, Perkinson SG, Ablove RH, Tueting JL. Distal Biceps Tendon Ruptures: An Epidemiological Analysis Using a Large Population Database. Am J Sports Med. 2015 Aug;43(8):2012–7.
3. Laszlo S, Jonsson KB. Increasing incidence of surgically treated hamstring injuries: a nationwide registry study in Sweden between 2001 and 2020. Acta Orthop. 2023 Jul 4;94:336–41.
4. Clayton RAE, Court-Brown CM. The epidemiology of musculoskeletal tendinous and ligamentous injuries. Injury. 2008 Dec 1;39(12):1338–44.
5. Spoendlin J, Meier C, Jick SS, Meier CR. Oral and inhaled glucocorticoid use and risk of Achilles or biceps tendon rupture: a population-based case-control study. Annals of Medicine. 2015 Aug 18;47(6):492–8.
6. Trobisch PD, Bauman M, Weise K, Stuby F, Hak DJ. Histologic analysis of ruptured quadriceps tendons. Knee Surg Sports Traumatol Arthrosc. 2010 Jan;18(1):85–8.
7. Hoffmann A, Mamisch N, Buck FM, Espinosa N, Pfirrmann CWA, Zanetti M. Oedema and fatty degeneration of the soleus and gastrocnemius muscles on MR images in patients with Achilles tendon abnormalities. Eur Radiol. 2011 Sep;21(9):1996–2003.
8. Nelson M, Jersey A, Okumura Y, Stankard B. Bedside Ultrasound Diagnosis of Quadriceps Tendon Rupture and Avulsed Patella. Current Sports Medicine Reports. 2017 Jun;16(3):153.
9. Ciriello V, Gudipati S, Tosounidis T, Soucacos PN, Giannoudis PV. Clinical outcomes after repair of quadriceps tendon rupture: A systematic review. Injury. 2012 Nov 1;43(11):1931–8.
10. Hawkins CB, Abromitis R, van Eck C. Differences in risk factors exist for the occurrence of bilateral versus unilateral distal biceps tendon ruptures: a systematic review. Journal of ISAKOS. 2021 Sep 1;6(5):302–7.
11. Irger M, Willinger L, Lacheta L, Pogorzelski J, Imhoff AB, Feucht MJ. Proximal hamstring tendon avulsion injuries occur predominately in middle-aged patients with distinct gender differences: epidemiologic analysis of 263 surgically treated cases. Knee Surg Sports Traumatol Arthrosc. 2020 Apr 1;28(4):1221–9.
12. Abdelwahab A, Ahuja N, Iyengar KP, Jain VK, Bakti N, Singh B. Traumatic rotator cuff tears - Current concepts in diagnosis and management. J Clin Orthop Trauma. 2021 Apr 17;18:51–5.
13. Tarantino D, Palermi S, Sirico F, Corrado B. Achilles Tendon Rupture: Mechanisms of Injury, Principles of Rehabilitation and Return to Play. J Funct Morphol Kinesiol. 2020 Dec 17;5(4):95.
14. Leino O, Keskinen H, Laaksonen I, Mäkelä K, Löyttyniemi E, Ekman E. Incidence and Treatment Trends of Achilles Tendon Ruptures in Finland: A Nationwide Study. Orthop J Sports Med. 2022 Nov 8;10(11):23259671221131536.
15. Reito A, Paloneva J, Mattila VM, Launonen AP. The increasing incidence of surgically treated quadriceps tendon ruptures. Knee Surg Sports Traumatol Arthrosc. 2019;27(11):3644–9.
16. Borodulin K, Laatikainen T, Juolevi A, Jousilahti P. Thirty-year trends of physical activity in relation to age, calendar time and birth cohort in Finnish adults. Eur J Public Health. 2008 Jun;18(3):339–44.
17. Nori S. Quadriceps tendon rupture. J Family Med Prim Care. 2018;7(1):257–60.
18. Xergia SA, Tsarbou C, Liveris NI, Hadjithoma M, Tzanetakou IP. Risk factors for Achilles tendon rupture: an updated systematic review. The Physician and Sportsmedicine. 2023 Nov 2;51(6):506–16.
19. Morales DR, Slattery J, Pacurariu A, Pinheiro L, McGettigan P, Kurz X. Relative and Absolute Risk of Tendon Rupture with Fluoroquinolone and Concomitant Fluoroquinolone/Corticosteroid Therapy: Population-Based Nested Case–Control Study. Clin Drug Investig. 2019;39(2):205–13.
20. Ahn HS, Kim HJ, Suh JS, Kazmi SZ, Kang TU, Choi JY. The Association of Body Mass Index and Waist Circumference with the Risk of Achilles Tendon Problems: A Nationwide Population-Based Longitudinal Cohort Study. Clin Orthop Surg. 2023 Jun;15(3):488–98.

21. Scott A, Zwerver J, Grewal N, de Sa A, Alktebi T, Granville DJ, et al. Lipids, adiposity and tendinopathy: is there a mechanistic link? Critical review. Br J Sports Med. 2015 Aug;49(15):984–8.
22. Macchi M, Spezia M, Elli S, Schiaffini G, Chisari E. Obesity Increases the Risk of Tendinopathy, Tendon Tear and Rupture, and Postoperative Complications: A Systematic Review of Clinical Studies. Clin Orthop Relat Res. 2020 Aug;478(8):1839–47.
23. Abate M, Vanni D, Pantalone A, Salini V. Cigarette smoking and musculoskeletal disorders. Muscles Ligaments Tendons J. 2013 Jul 9;3(2):63–9.
24. Mr S, Sm G. Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. Clinical orthopaedics and related research [Internet]. 2002 Nov [cited 2024 Aug 15];(404). Available from: https://pubmed-ncbi-nlm-nih-gov.libproxy.tuni.fi/12439270/
25. Hijlkema A, Roozenboom C, Mensink M, Zwerver J. The impact of nutrition on tendon health and tendinopathy: a systematic review. J Int Soc Sports Nutr. 19(1):474–504.
26. van der Vlist AC, Breda SJ, Oei EHG, Verhaar JAN, de Vos RJ. Clinical risk factors for Achilles tendinopathy: a systematic review. Br J Sports Med. 2019 Nov;53(21):1352–61.
27. Zakaria MHB, Davis WA, Davis TME. Incidence and predictors of hospitalization for tendon rupture in Type 2 diabetes: the Fremantle Diabetes Study. Diabetic Medicine. 2014;31(4):425–30.
28. Spoendlin J, Meier C, Jick SS, Meier CR. Achilles or biceps tendon rupture in women and men with type 2 diabetes: A population-based case-control study. J Diabetes Complications. 2016 Jul;30(5):903–9.
29. Claessen FMAP, de Vos RJ, Reijman M, Meuffels DE. Predictors of Primary Achilles Tendon Ruptures. Sports Med. 2014 Sep 1;44(9):1241–59.
30. Aicale R, Tarantino D, Maffulli N. Overuse injuries in sport: a comprehensive overview. Journal of Orthopaedic Surgery and Research. 2018 Dec 5;13:309.
31. Wang J, Geng L. Effects of Socioeconomic Status on Physical and Psychological Health: Lifestyle as a Mediator. International Journal of Environmental Research and Public Health. 2019 Jan;16(2):281.
32. Hoyt LT, Chase-Lansdale PL, McDade TW, Adam EK. Positive youth, healthy adults: Does positive well-being in adolescence predict better perceived health and fewer risky health behaviors in young adulthood? J Adolesc Health. 2012 Jan;50(1):66–73.
33. Socioeconomic deprivation status predicts both the incidence and nature of Achilles tendon rupture - PubMed [Internet]. [cited 2024 Dec 8]. Available from: https://pubmed-ncbi-nlm-nih-gov.libproxy.tuni.fi/36066575/
34. Sun K, Ming Y, Wu Y, Zeng Y, Xu J, Wu L, et al. The Genetic Causal Association between Educational Attainment and Risk of 12 Common Musculoskeletal Disorders: A Two-Sample Mendelian Randomization. Orthopaedic Surgery. 2023 Sep 7;15(11):2814.
35. Mackenbach JP, Stirbu I, Roskam AJR, Schaap MM, Menvielle G, Leinsalu M, et al. Socioeconomic inequalities in health in 22 European countries. N Engl J Med. 2008 Jun 5;358(23):2468–81.
36. Pickett W, Dostaler S, Craig W, Janssen I, Simpson K, Shelley SD, et al. Associations between risk behavior and injury and the protective roles of social environments: an analysis of 7235 Canadian school children. Inj Prev. 2006 Apr;12(2):87–92.
37. Tampere universities. Tampere universities. 2024 [cited 2024 Aug 1]. The Adolescent Health and Lifestyle Survey (AHLS). Available from: https://www.tuni.fi/en/research/adolescent-health-and-lifestyle-survey-ahls
38. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000 May 6;320(7244):1240–3.
39. Sund R. Quality of the Finnish Hospital Discharge Register: a systematic review. Scand J Public Health. 2012 Aug;40(6):505–15.
40. Huttunen TT, Kannus P, Pihlajamäki H, Mattila VM. Pertrochanteric fracture of the femur in the Finnish National Hospital Discharge Register: validity of procedural coding, external cause for injury and diagnosis. BMC Musculoskelet Disord. 2014 Mar 24;15:98.
41. Mattila VM, Sillanpää P, Iivonen T, Parkkari J, Kannus P, Pihlajamäki H. Coverage and accuracy of diagnosis of cruciate ligament injury in the Finnish National Hospital Discharge Register. Injury. 2008 Dec;39(12):1373–6.
42. Textor J, van der Zander B, Gilthorpe MS, Liskiewicz M, Ellison GT. Int J Epidemiol. 2016 Dec 1;45(6):1887–94.
43. Byeon S, Lee W. Directed acyclic graphs for clinical research: a tutorial. J Minim

Invasive Surg. 2023 Sep 15;26(3):97–107.

44. Lemme NJ, Li NY, DeFroda SF, Kleiner J, Owens BD. Epidemiology of Achilles Tendon Ruptures in the United States: Athletic and Nonathletic Injuries From 2012 to 2016. Orthop J Sports Med. 2018 Nov 26;6(11):2325967118808238.

45. Chou PS, Huang SH, Chung RJ, Huang YC, Chung CH, Wang BL, et al. Gender Differences in the Epidemiological Characteristics and Long-Term Trends of Injuries in Taiwan from 1998 to 2015: A Cross-Sectional Study. Int J Environ Res Public Health. 2022 Feb 22;19(5):2531.

46. Hallal PC, Victora CG, Azevedo MR, Wells JCK. Adolescent physical activity and health: a systematic review. Sports Med. 2006;36(12):1019–30.

47. Rejeb A, Johnson A, Vaeyens R, Horobeanu C, Farooq A, Witvrouw E. Compelling overuse injury incidence in youth multisport athletes. European Journal of Sport Science. 2017;17(4):495–502.

48. Zaremski JL, Giorgio Zeppieri J, Tripp BL. Sport Specialization and Overuse Injuries in Adolescent Throwing Athletes: A Narrative Review. Journal of Athletic Training. 2019 Oct;54(10):1030.

49. Jayanthi N, Pinkham C, Dugas L, Patrick B, LaBella C. Sports Specialization in Young Athletes: Evidence-Based Recommendations. Sports Health. 2013 May;5(3):251.

50. Matava MJ, Purcell DB, Rudzki JR. Partial-Thickness Rotator Cuff Tears. Am J Sports Med. 2005 Sep 1;33(9):1405–17.

51. Gabbett TJ, Kennelly S, Sheehan J, Hawkins R, Milsom J, King E, et al. If overuse injury is a 'training load error', should undertraining be viewed the same way? Br J Sports Med. 2016 Sep 1;50(17):1017–8.

52. Lui PPY, Zhang X, Yao S, Sun H, Huang C. Roles of Oxidative Stress in Acute Tendon Injury and Degenerative Tendinopathy—A Target for Intervention. International Journal of Molecular Sciences. 2022 Mar 25;23(7):3571.

53. Abate M, Schiavone C, Salini V, Andia I. Occurrence of tendon pathologies in metabolic disorders. Rheumatology. 2013 Apr 1;52(4):599–608.

54. Noback PC, Jang ES, Cuellar DO, Seetharaman M, Malagoli E, Greisberg JK, et al. Risk factors for achilles tendon rupture: A matched case control study. Injury. 2017 Oct 1;48(10):2342–7.

55. Clark ST, Zhu M, Gamble GD, Naot D, Paine SJ, Dalbeth N, et al. Epidemiology of tendon and ligament injuries in Aotearoa/New Zealand between 2010 and 2016. Inj Epidemiol. 2020 Feb 10;7(1):5.

56. Fosse NE, Haas SA. Validity and Stability of Self-reported Health Among Adolescents in a Longitudinal, Nationally Representative Survey. Pediatrics. 2009 Mar 1;123(3):e496–501.

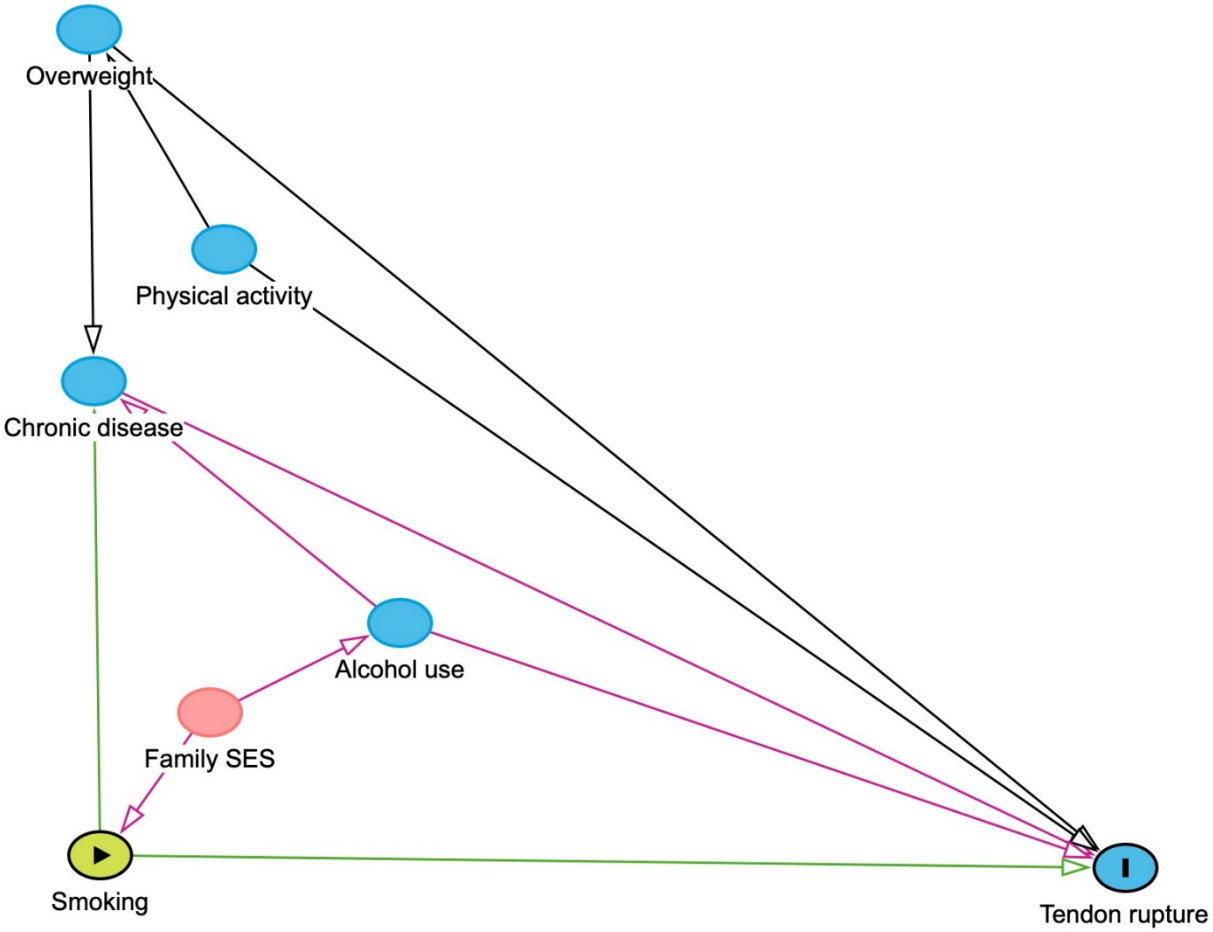
57. Del Boca FK, Darkes J. The validity of self-reports of alcohol consumption: state of the science and challenges for research. Addiction. 2003 Dec;98 Suppl 2:1–12.

Supplementary material

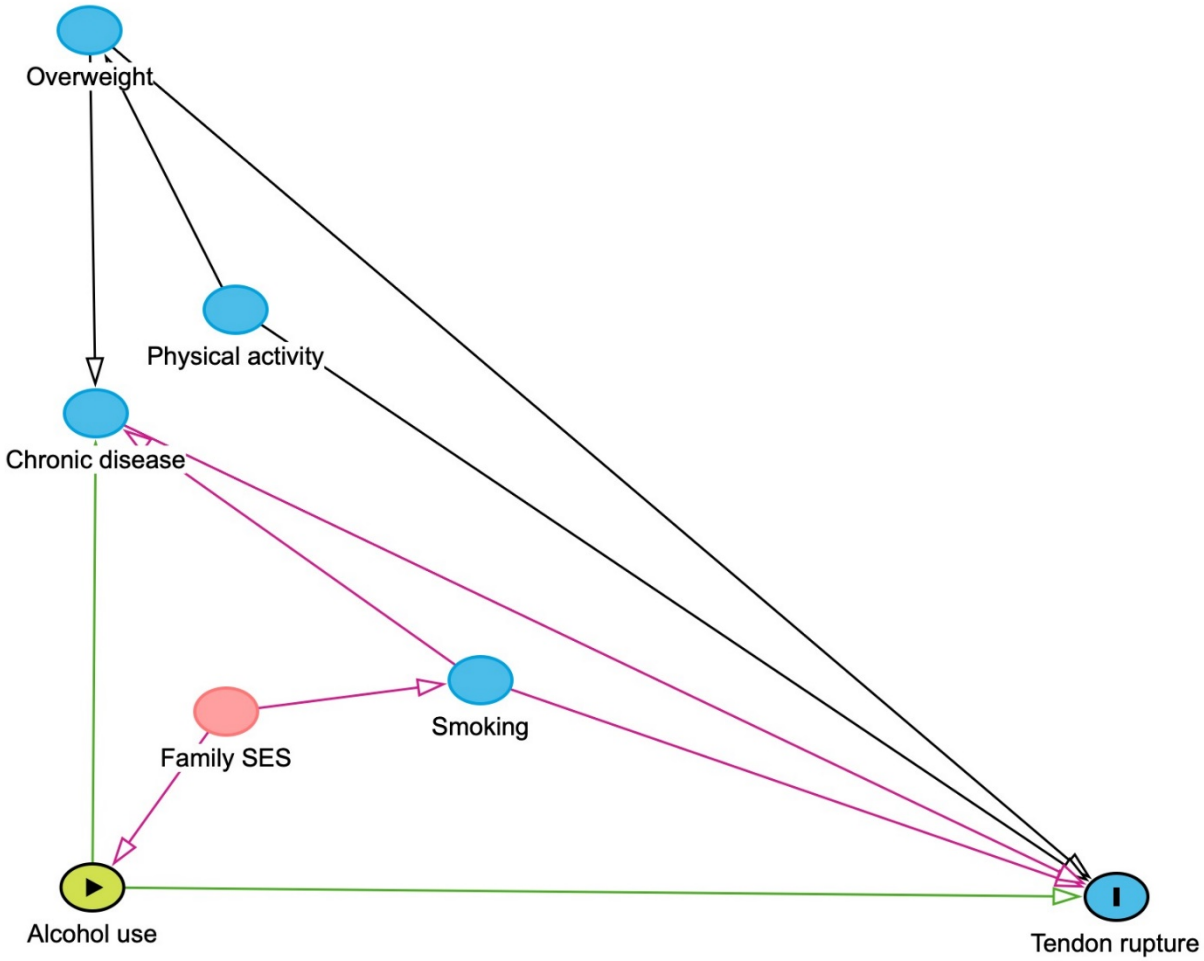
Supplementary table 1. Frequencies of the answers in the variables used.

	All (%)	Female (%)	Male (%)
Daily smoking			
No	35 837 (75.1)	19 734 (76.7)	16 103 (73.1)
Yes	11 564 (24.2)	5 874 (22.8)	5 690 (25.9)
Unknown	346 (0.7)	119 (0.5)	227 (1.0)
Drinking style			
Abstinence	20 449 (42.8)	11 066 (43.0)	9 383 (42.6)
Occasional drinking	17 888 (37.5)	10 352 (40.2)	7 536 (34.2)
Recurrent drinking	7 460 (15.6)	3 567 (13.9)	3 893 (17.7)
Recurring drunkenness	1 588 (3.3)	589 (2.3)	999 (4.5)
Unknown	362 (0.8)	153 (0.6)	209 (1.0)
Frequency of participation in leisure sports			
Never	2 355 (4.9)	1 076 (4.2)	1 279 (5.8)
2-3 times a week	33 406 (70.0)	18 675 (72.6)	14 731 (66.9)
4 or more times a week	11 324 (23.7)	5 731 (22.3)	5 593 (25.4)
Unknown	662 (1.4)	245 (0.9)	417 (1.9)
Frequency of participation in sports clubs			
Never	27 639 (57.9)	16 470 (64.0)	11 169 (50.7)
2-3 times a week	14 600 (30.6)	7 358 (28.6)	7 242 (32.9)
4 or more times a week	4 391 (9.2)	1 412 (5.5)	2 979 (13.5)
Unknown	1 117 (2.3)	487 (1.9)	630 (2.9)
Overweight			
No	41 702 (87.4)	23 143 (90.0)	18 559 (84.3)
Yes	4 839 (10.1)	2 001 (7.8)	2 838 (12.9)
Unknown	1 206 (2.5)	583 (2.2)	623 (2.8)
Chronic disease			
No	41 950 (87.8)	22 561 (87.7)	19 389 (88.1)
Yes	4 229 (8.9)	2 407 (9.4)	1 822 (8.3)
Unknown	1 568 (3.3)	759 (2.9)	809 (3.6)
Parental educational level			
Both high	2 532 (5.3)	1 332 (5.2)	1 200 (5.4)
Either one high	5 404 (11.3)	2 835 (11.0)	2 569 (11.7)
Either one middle	28 877 (60.5)	15 601 (60.6)	13 276 (60.3)

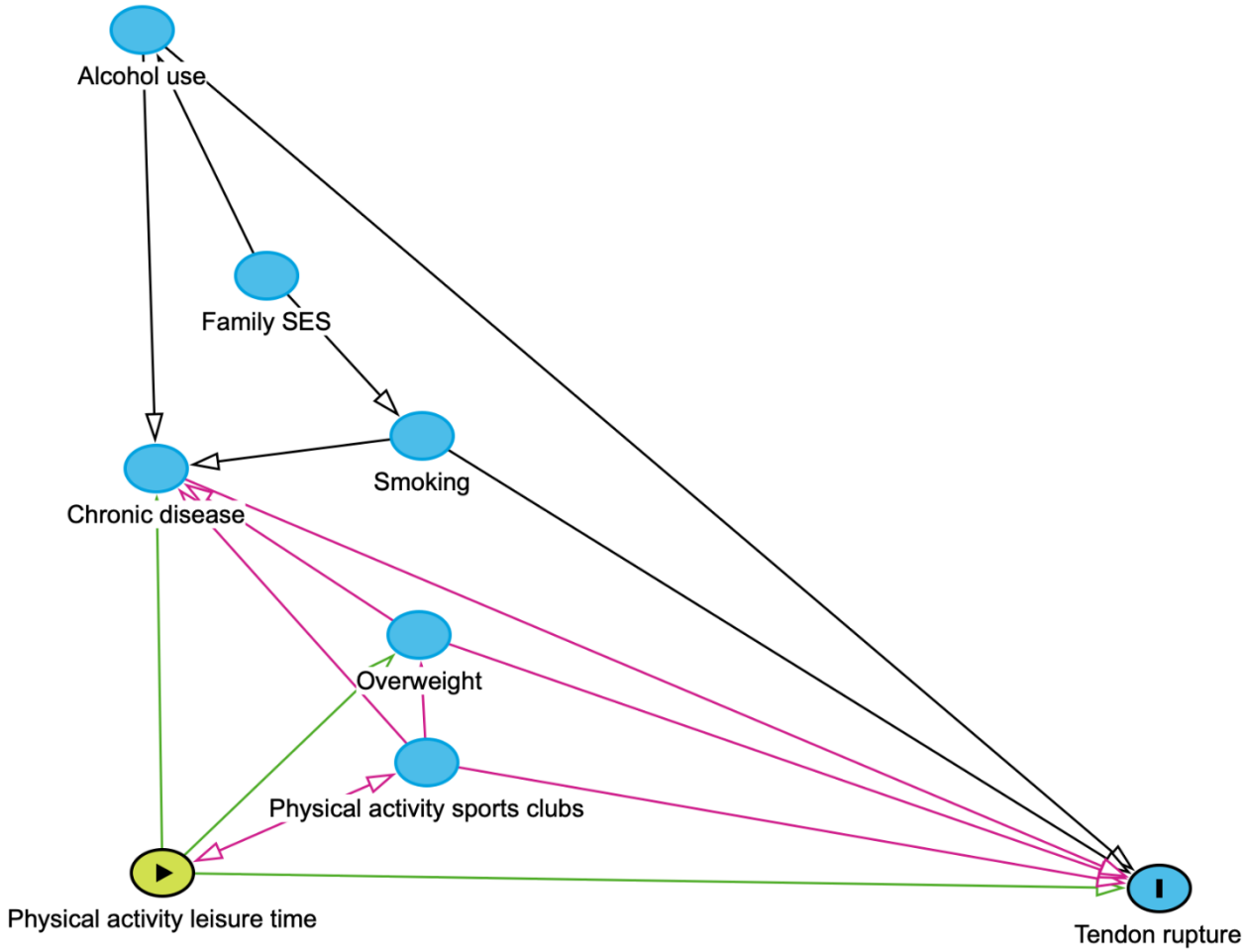
Both low	10 909 (22.8)	5 945 (23.1)	4 964 (22.5)
Unknown	25 (0.1)	14 (0.1)	11 (0.1)
Parental occupational status			
Both upper-white-collar	7 775 (16.3)	4 098 (15.9)	3 677 (16.7)
Either one upper white-collar	11 899 (24.9)	6 443 (25.0)	5 456 (24.8)
Either one lower white-collar	15 184 (31.8)	8 091 (31.5)	7 093 (32.2)
Either one blue-collar	10 423 (21.8)	5 776 (22.5)	4 647 (21.1)
Both unknown	2 466 (5.2)	1 319 (5.1)	1 147 (5.2)



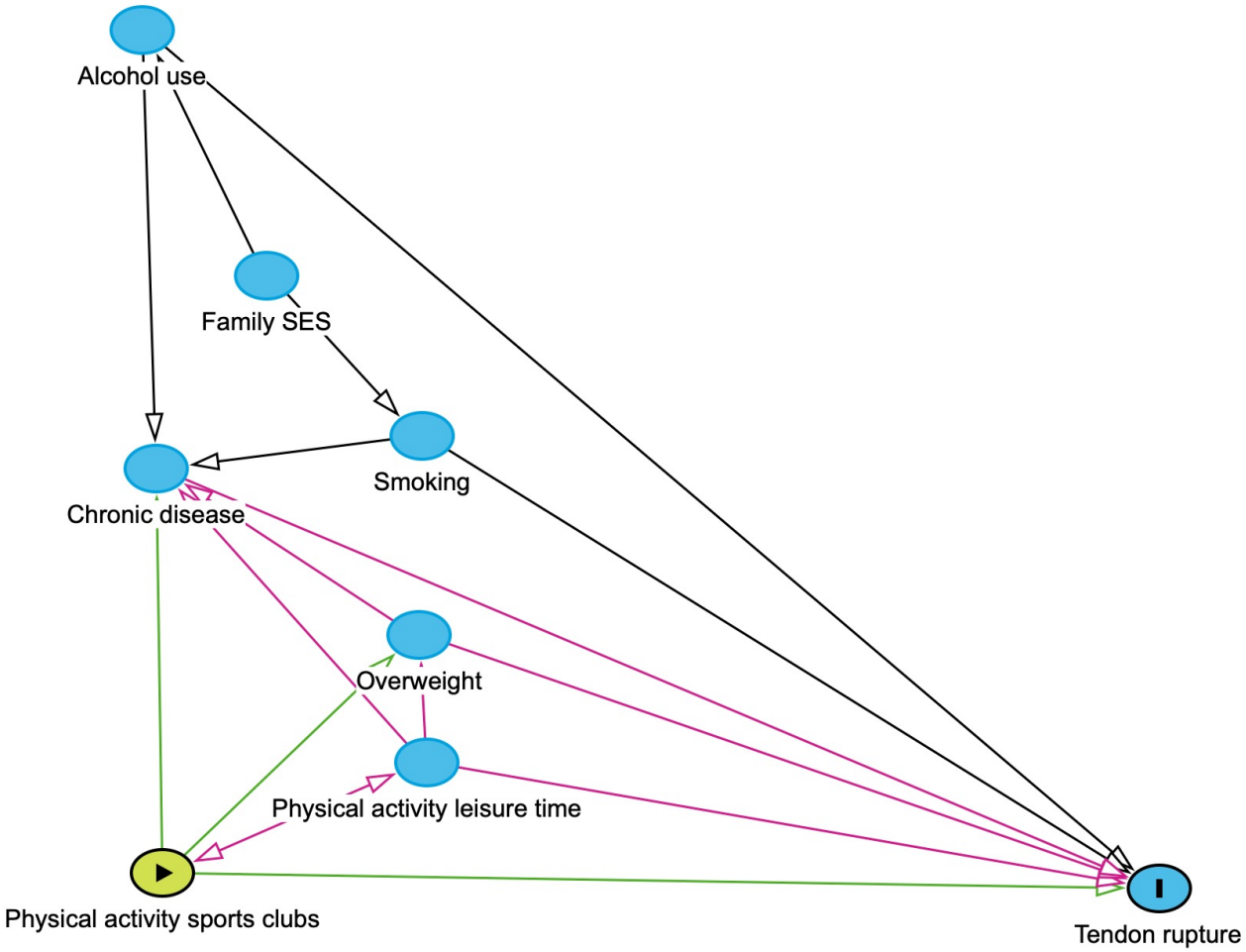
Supplementary figure 1. DAG: Smoking and the risk for tendon rupture.



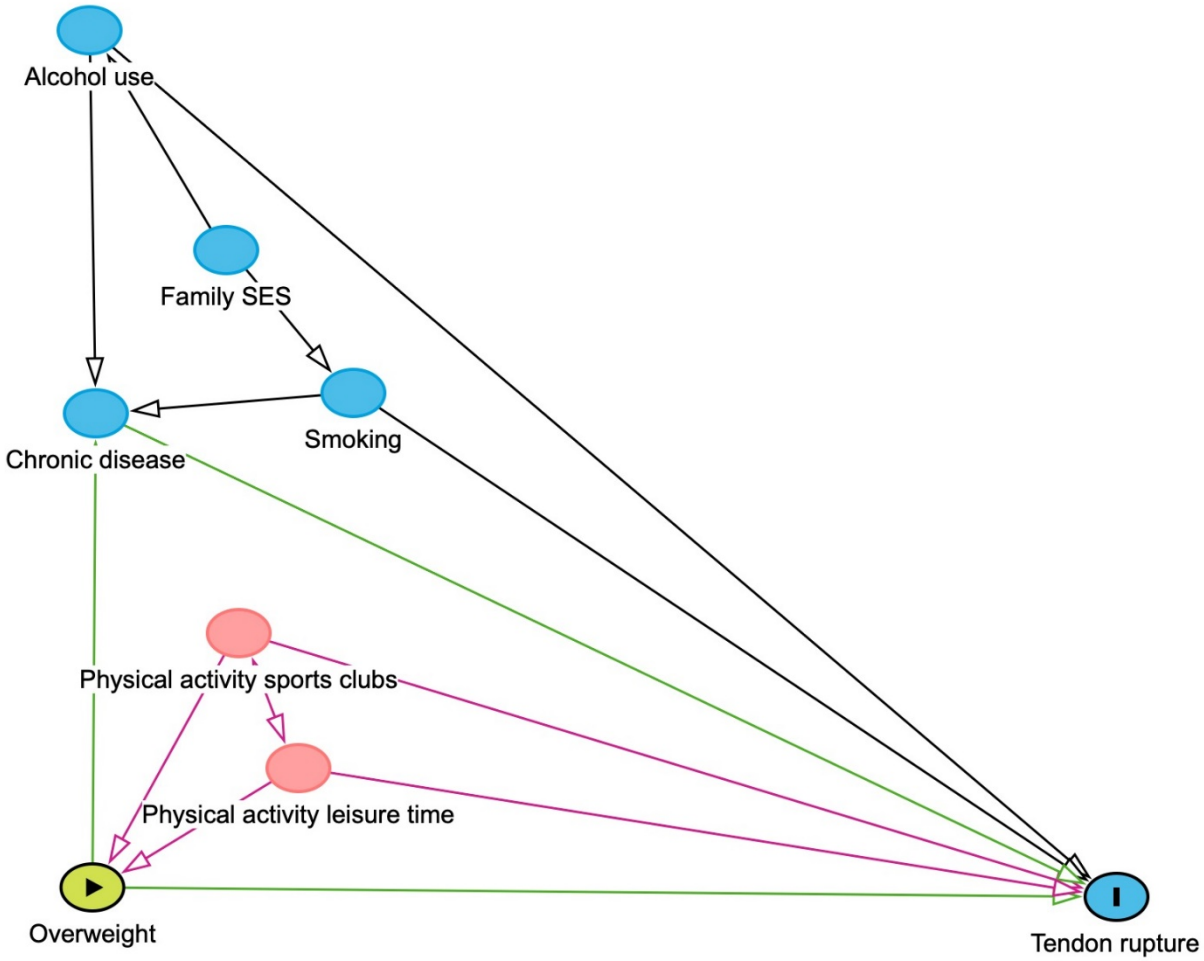
Supplementary figure 2. DAG: Alcohol use and the risk for tendon rupture.



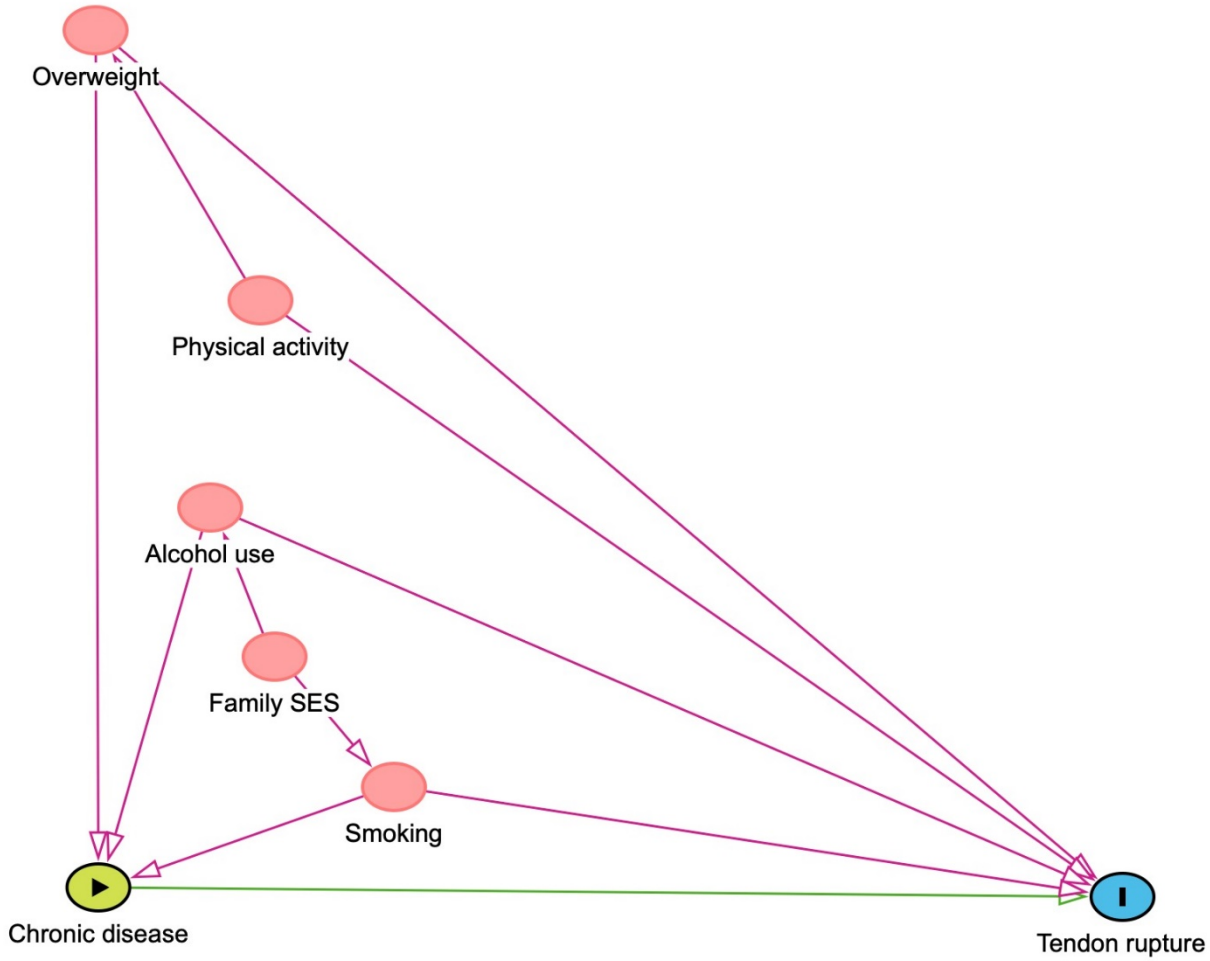
Supplementary figure 3. DAG: Physical activity in leisure time and the risk for tendon rupture.



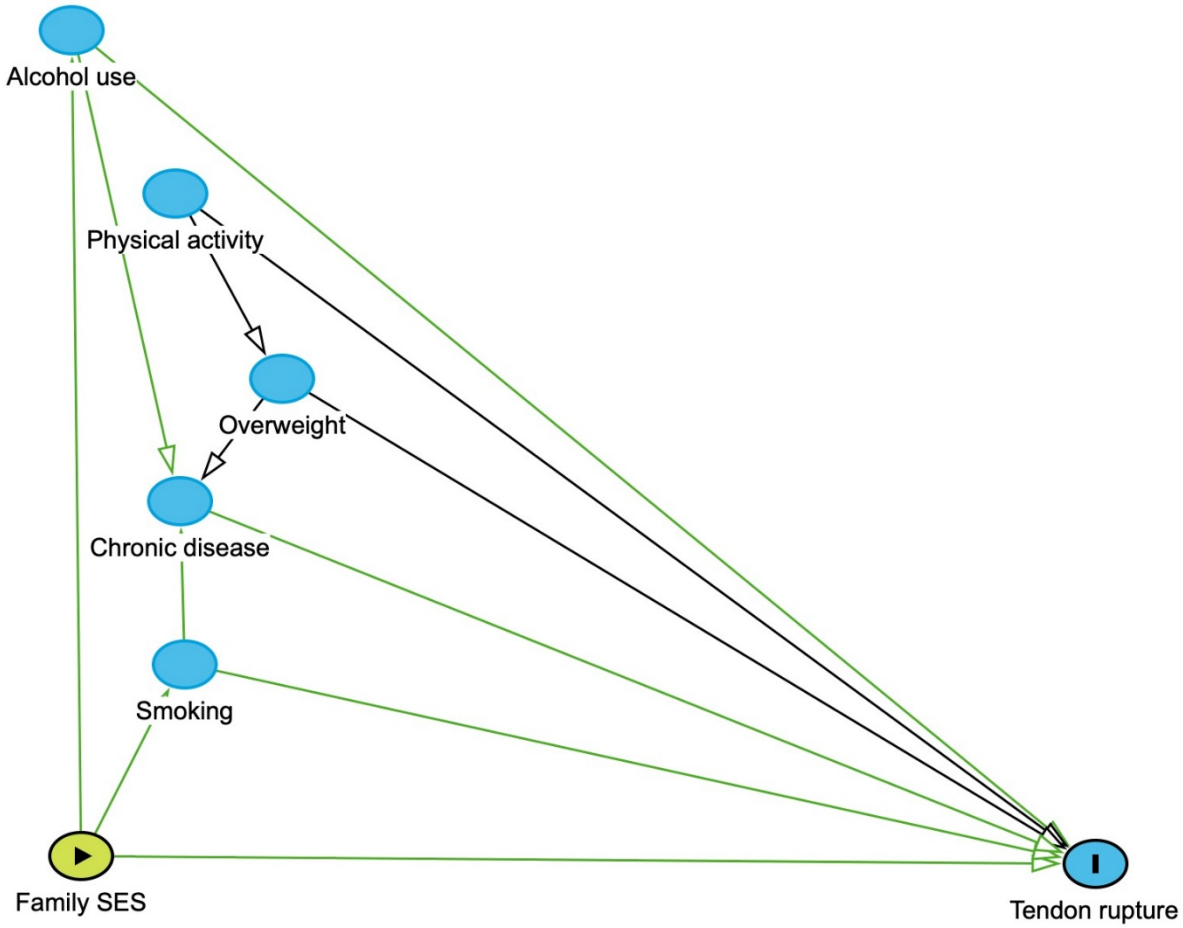
Supplementary figure 4. DAG: Physical activity in sports clubs and the risk for tendon rupture.



Supplementary figure 5. DAG: Overweight and the risk for tendon rupture.



Supplementary figure 6. DAG: Chronic disease and the risk for tendon rupture.



Supplementary figure 7. DAG: Family SES and the risk for tendon rupture.