Comparison of Sport Activity in Patients with Ankle OA and after Arthrodesis or Total Ankle Arthroplasty, Review of the Current Literature

Dr. Francisco Guillermo Castillo-Vazquez, Dr. Simone Santini, Prof. Dr. med. Dr. phil. Victor Valderrabano

Ankle osteoarthritis (OA) is a chronic painful disease associated with physical impairment and limited well-being 1,2,3,4,5,6,7,42, 60. It is suffered by 1% of the population, and its incidence is increasing yearly 1,3. Furthermore, the physical and psychological difficulties these patients report are at least as severe and debilitating as those from hip OA, end-stage kidney disease, or congestive heart failure 1,3, 4,5, 6, 8,9,13,15, 17, 78.

Certain ankle OA characteristics generate specific problems that need to be assessed 1, 2, 3. Unlike other joints in which the leading cause of articular degeneration is primary, in the ankle, articular incongruity and instability are the main predisposing factors (close to 80% of the cases), both associated with previous trauma 1, 2, 3,6, 8. Posttraumatic osteoarthritis is more symptomatic, rapidly progressive, and incapacitating than primary OA 2,3, 4, 6, 8. Another important consideration is the continuous increase in the population of all ages performing physical activity. In the United Kingdom, the number of individuals participating in sports activities at least once a week rose by 750,000 from 2011 to 2012 9. This situation has raised the incidence of sports-related injuries, especially in the ankle, due to its fundamental role in lower limb biomechanics 6. Indeed ankle lesions had been reported as the second leading cause of career-ending injuries, the most common lesion in athletes seen in the emergency departments, and as a significant contributor to ankle OA (15% of former soccer players suffer from it) 6, 8,9, 16, 17, 18, 19, 20.

All this leaves us with a younger and more active population suffering from ankle OA compared to hip or knee patients, where individuals have high work and family demands and are typically active in sports and other recreational activities 4. That is why assuring a functional joint capable of maintaining a good activity level in these patients is of paramount importance 3,4, 5, 6, 7, 8, 9. This article will focus on understanding the impairments that affect patients with ankle OA, especially the ones related to sports activity, and on the effectiveness of the two main treatment options available nowadays (total ankle replacement (TAR) and ankle arthrodesis (AA)) to address these problems and return patients to their former performance.

Physical and Psychological Impairments Associated with Ankle Osteoarthritis

The contribution of the ankle to many essential tasks needed to perform physical activities has been investigated recently in the literature. Kostifakis et al. reported that the ankle was responsible for 35% of the propulsion and 37% of the landing capacity during a vertical hoop test (jump height) and at the same manner of 43% of the distance and 11% of the landing ability during a horizontal hoop distance test (jump distance) 9. This study reveals the importance of ankle health in sports performance.

Many biomechanical disturbances have been reported in the literature in patients suffering from ankle OA. Al-Mahrouqi et al. performed a systematic review and meta-analysis of the literature. They found that adults with ankle OA had significant impairments in ankle sagittal plane range of motion, impairment in balance, abnormal bony alignments, and fatty infiltrate in all calf muscle compartments 13, 15. In concordance with the previous study, Wiewiorski et al. proved that unilateral ankle joint osteoarthritis leads to overall lower leg muscle atrophy and fatty degeneration 33. Gait patterns are also disturbed in patients with ankle OA, affecting their general well-being and locomotion 22, 23. This alteration in gait patterns is associated with more significant energy expenditure. It can affect other parts of the lower extremities' biomechanics, such as the hip range of motion, to compensate for the loss of ankle movement 29, 32,42,51. Another critical parameter for sports activity affected by ankle OA is balanced. Wikstrom et al. determined that OA patients had a destructive peak vertical ground reaction force during the weight acceptance phase of stairs ascent and descent, suggesting a reduced ability to control their body mass while climbing 22, 24, 25. Furthermore, a study by Smith et al. supports that patients with ankle OA have lower confidence in performing simple tasks compared to healthy controls 27, 30, 34.

As stated above, all these impairments are associated with alterations in performance in daily living, work, and sports. Rivera et al. described ankle OA as an increasing and substantial cause of disability among those serving in the military, finding that nearly all (91%) of ankle injuries in their cohort resulted in an eventual designation of permanent disability due to ankle OA 31. Indeed, Kolar et al. reported that patients with end-stage ankle OA had the worst subjective ankle status against other incapacitating ankle pathologies 21. Moreover, Yeowell et al. performed semi-structured interviews with a cohort of patients with ankle OA. They found that this pathology causes a significant reduction in physical activity and negatively impacts mental well-being 26.

This alteration in ankle joint biomechanics, gait patterns, balance, energy expenditure, and changes in other joints are reported by a vast amount of different outcome measurement tools with different validity in the literature for ankle OA 35,36,37,38,45,51,54,59 Alyani et al. analyzed 547 studies. They concluded that the most commonly used scales were the AOFAS scale, goniometry, and pain VAS 39. Of these findings, Madeley et al. and Naas et al. studied the responsiveness and validity of SF36, AOFAS, Ankle Osteoarthritis Scale (AOS), and Foot Function Index (FFI). They concluded that all of them are responsive and can be considered for use in this population; more important than this is the direct relations of these measurements with a return to physical activity and sports performance reported in the literature 40,45,54,59.

As a versatile biomechanical structure, the foot and ankle complex provides body support, propulsion, and impact absorption 83. Considering the incapacitating effect of untreated ankle OA on lower limb function and that surgical options have different capacities to change the function of this complex, and because of that, sports performance and quality of life. The effect of individualized surgical interventions on these parameters is worth considering 42, 83.

Alteration	**Specificities**
Ranges of motion 13,15,22,23	Decrease in movement, particularly in the sagittal plane
Activity of leg muscles 13, 15, 33	Deterioration of the activity seen in electromyography Fatty degeneration in MRI

Gait pattern 22, 23	Less push-off power Shorter step length Decrease walking velocity
Balance 27, 30, 34	Detrimental peak vertical ground reaction force during the weight acceptance phase Reduced ability to control body mass while stair climbing Lower confidence while performing simple tasks Greater center of pressure areas when standing on a surface with eyes closed
Energy expenditure 29	Significant increase in metabolic cost
Compensatory changes 32, 42, 51	Alteration of hip biomechanics specifically during the push-off phase of the gait

Table 1. Physical Disturbances Associated with Ankle OA

Sports and Recreational Activities Following Total Ankle Replacement

Total ankle replacement is a treatment option for end-stage ankle OA that allows surgeons to restore normal joint function 41, 59. Recent biomechanical studies, prospective controlled trials, and meta-analyses have suggested that new TAR anatomical designs afford equivalent pain relief and better function than ankle arthrodesis with a survival rate of 70% to 98% at three to six years and from 80% to 95% at eight to twelve years and increasing 54,55,56, 59. The biomechanical effect of TAR in arthritic ankles has been well described in the literature. Valderrabano et al. followed 15 patients preoperatively and at different stages of their TAR recovery until one year and compared them with 15 healthy controls with 3D kinematics and motion analysis 80. Before the operation, they reported deficiencies in 5 Spatio-temporal variants (shorter stride length, reduced walking speed, shorter stance phase duration of the affected leg, triplanar ankle movement, and substantially reduced push-off power). While at 12 months follow-up, all variables were equivalent to those of normal subjects (end of full rehabilitation) 80.

As presented before, even though some functional scales do not report sports activity directly, a higher score in these measurements (SF36, AOFAS, AOS, and FFI) is directly related to a better performance in physical activity 43,44,46,48. In agreement with this, McConnell and Queen assessed 140 patients with end-stage ankle OA before, 12, and 24 months after TAR using VAS, FADI, AOFAS, and SF-36 scores. They found that outcomes improved significantly from preoperative assessment to 1 and 2 years postoperatively 47. Supporting this finding, Oliver et al. reviewed data from 300 consecutive patients who underwent 321 modern, fixed-bearing TAR at a single institution. They found that 84% of patients experienced excellent pain relief, 78% reported improved ability to perform daily tasks, and 54% indicated improvement in their ability to perform heavy work or recreational activities. In addition, 94% would have the procedure on the contralateral ankle 48.

There is an increasing amount of evidence regarding specific sport activity after TAR.
Fram et al. showed that the outcomes of 43 patients with a 2-component TAR significantly improved sports activity at 27.4 months postoperatively 61. Furthermore, Usuelli et al. found that patients with symptomatic end-stage OA who underwent total ankle replacement (TAR) had significantly improved pain, function, and activity levels at 1-year follow-up 43. Moreover,

Naal et al. found that 65% of patients stated that surgery improved their sports ability, and 79% met current guidelines for health-enhancing physical activity following TAR 44, 54. In addition, Bonnin et al. reported that TAR improved patients' quality of life and that return to recreational activities was generally possible, even though the return to impact sport was rarely plausible 46,54. Finally, Valderrabano et al. found that 152 ankle arthritis patients had better self-reported satisfaction, a higher grade of motion, a higher AOFAS score, and were able to perform generally in high-level sports after TAR 52,54.

However, some evidence has highlighted essential aspects that need to be assessed when studying outcomes in patients receiving a TAR. The two most important to consider are the type of OA and the model of the selected implant. Cho et al. revealed that physical activity after TAR is not the same for patients with different causes of ankle OA. They compared 45 patients with posttraumatic ankle OA with 19 patients with end-stage rheumatoid arthritis (RA). They found that patients with posttraumatic ankle OA showed better scores in leisure and sports activity subscales than patients with OA secondary to rheumatoid arthritis 49. The design of TAR can also influence outcomes, as said by Rajan et al. in a retrospective study where INBONE II (2-sphere fitting design that is purported to approximate the talar trochlea closely) showed significantly higher postoperative pain, symptoms, and sports activity scores than Salto Talaris (2 radii of curvature and metal resurfacing of the lateral condyle design) 62.

Another critical point is the amount of activity patients performed before TAR. This is answered by Valderrabano et al., who compared AOFAS hindfoot scores and sports activity in patients pre and post-TAR and found that sports-active TAR patients had a significant positive correlation with both scores compared to the inactive cohort 89.

A final important point to consider is that the total amount of sports activity after TAR could be limited by surgeon's restrictions, as a survey conducted by McCaulay et al. shows. In this study, foot and ankle surgeons were asked about the restraints they would place in patients after TAR in 50 different sports and activities. They were comfortable with aerobic or low-impact sports like swimming, walking, and biking. However, boot-immobilized sports represented a gray area with the determination of whether or not to allow them, mainly based on the patient's prior experience. In contrast, high-impact, cutting, and jumping sports and activities were discouraged 53. These restrictions are supported by Valderrabano et al., who presents a series of advice for TAR patients based on previous guidelines in total hip, total knee, and ankle arthrodesis patients 52. This can suggest that the return to sports and degree of physical activity in patients after TAR could even be higher than reported, but surgeons' advice limits it.

Sports and Recreational Activities Following Ankle Arthrodesis (AA)

Arthrodesis of the ankle is a well-known orthopedic procedure performed for end-stage ankle OA with a high degree of satisfaction reported by patients 60, 72. Even so, a critical systematic review of the literature shows that these positive results are mainly based on questionnaires that focus on pain and disability in daily life, while information concerning the performance of more demanding tasks is limited 57,58, 75, 78.

Correction of significant deformities and pain alleviation had been mentioned as the main advantages of this procedure. However, there is well-documented information about the biomechanical disturbances and stress it can place in other regions of the lower limbs 57,58. Wu et al. demonstrated in a computerized motion analysis system that sagittal plane motion of the ankle was significantly decreased, while coronal and transverse planes of movement raised in the subtalar joint and forefoot in patients after AA compared to controls 57. This work is supported by van der Plaat et al., who highlighted that increased peak pressure in subtalar, talonavicular, and calcaneocuboid joints that occurred after AA caused degenerative changes and, consequently, osteoarthritis of these regions 58. In addition, Fuchs et al. used standing radiographs in 18 patients 20 years after TAA to determine the alterations in adjacent joints. They found osteoarthritis in 100% of the cases, with 90% being grade 3 or 4 in the subtalar and 65% in the talonavicular joint 67. These changes have been reported as soon as four years after fusion and are highly relevant to functional outcomes as reported by previous authors 69, 70, 71.

However, not only the hindfoot suffers changes in patients after TAA. Beyaert et al. realized a three-dimensional gait analysis of foot kinematics. They declared that patients after tibiotalar arthrodesis suffer changes in foot kinematics and ground reaction force, increasing the stress applied to the mid and forefoot 63. In addition, Van Engelen et al. also showed that TAA results in a 16% decrease in walking speed and a 10% increase in oxygen consumption compared to healthy controls 64, 65, 66.

All these biomechanical disturbances relate to the physical impairment seen in patients after AA. Fuchs et al. stated from their follow-up group that 50% of their patients postAA reported handicaps in daily activities, with 64% changing to lighter employees 67, 68. Supporting these studies, Lynch et al. reported that seven years after AA, half of their cohort reported not working or had looked for a less strenuous job, and none were involved in active athletics 73.

Due to the growing importance of physical activity as a parameter of quality of life, many other studies have placed hands-on work to evaluate the amount and level of sports performed after AA. Kerkhoff et al. realized a follow-up study in 185 patients with a mean time of 8 years after AA and found that most patients remained active in sports. However, a transition to less demanding sporting activities was seen globally 75. In this same study, they could compare their results with those of a previously reported study of 67 patients after TAR, where they realized the same questionnaire. They found a slight difference in sports activity favorable to the TAR group (73 vs. 69%) but more important than these. The TAR group did not present significant changes in the type of sport conducted, with 10% of the patients who were inactive before surgery resuming activities postoperatively 75,76.

Direct Comparison in Return to Sports and Physical Activity Between TAR and AA

With the advent of TAR, more studies have started comparing the outcomes between AA and TAR. However, just a few of them treated the case of physical activity, return to sports, or similar characteristics. We summarized the findings related to this theme to date.

Newer TARs advantages have challenged the place of AA as the first-line treatment for end-stage ankle OA. First, the gait pattern is an important parameter associated with physical activity that must be evaluated while comparing these two treatment options. On this Segal. et al. recruited 47 patients scheduled for surgery (27 TAR / 20 AA). They compared them for a three-year follow-up using functional outcomes, gait analysis measures, and average daily step count. Both groups had improved walking speed and reduced pain after surgery, but AA patients had more significant sagittal hip ROM and stepped length 81. This information is consistent with the study by Sanders et al., where they compared 3-dimensional foot and ankle kinetics and kinematics between 10 TAR and 10 AA-matched patients with a minimum follow-up of 2 years. They observed that TAR patients had higher ankle range of motion, forefoot-tibia motion, and hindfoot-tibia motion during level walking and stair ascent than AA-matched patients. This increased TAR patient's ability to perform activities of daily living and sports compared with AA 77, 82. Another study evaluating the biomechanical difference in the foot after end-stage OA procedures is the one by Wang et al. using a validated analysis of finite elements simulating the stance phase of gait in models of the regular foot, postTAR, and postAA. Their results showed that TAR demonstrated a mild shift in forefoot angulation with a stable plantar pressure distribution. On the other hand, changes in AA were more severe and generated consequences in force transmission among segments, joint contact pressure, and higher stress distribution to the metatarsal bones 83.

These studies are consistent with newer papers that reported differences in outcomes, including quality of life between these two treatment modalities 84. Saltzman et al. reported the outcomes of 71 patients (42 TAR / 29 AA) with a mean follow-up of 4.2 years. They encountered that the SF36 MCS scale presented significantly relevant higher scores in the TAR group compared to AA patients 84. In the same issue, Sangeorzan et al. conducted a multisite prospective cohort study that included 517 participants (414 TAR and 103 AA) who presented for surgical treatment. Participants were compared 48 months after surgery using the FAAM Activities of Daily Living and Sports subscales, the SF-36 Physical and Mental Component Summary (PCS and MCS) scores, and VAS. Both groups achieved significant improvement. However, they found that patients undergoing TAR had more considerable mean improvements from baseline in the three measures of foot and ankle function than those undergoing AA 85, 87, 93. Table 2 summarizes the biomechanical, clinical and functional differences between healthy individuals and patients with ankle OA, postTAR and postAA.

	Healthy individual	**Ankle OA**	**TAR**	**AA**
Ankle range of motion 22, 23, 32, 42, 51, 81	Normal	Reduce	Normal	Absent
Biomechanical disturbances to the lower limbs 32, 42, 51, 81	Any	Higher range of motion and stress on the hip	Any	Higher range of motion and stress on the hip, subtalar, CC and TN joints Higher stress in the metatarsal bones
AOFAS (p 0.048) 94	100	19.8 ± 2.0	38.6 ± 1.4	26.9 ± 3.0

FAAM Sports (p<0.0001) 89	100	19.8 ± 2.0	38.6 ± 1.4	26.9 ± 3.0
SF-36 Mental Component (p0.001) 84	100		45.9	40.4

Table 2. Functional outcomes associated with sport performance between healthy controls and patients with ankle OA, TAR and AA.

It is essential to consider that different generations of TAR can also affect the postsurgical outcome of patients. Schuh et al. treated the relationship between return to sports, activity level, functional outcome, and the selected procedure for ankle OA (TAR or AA). They studied 41 patients (21 AA / 20 3 component uncemented 2nd generation TAR) with a mean follow-up of 34.5 months with no statistical difference between demographics 88. The Halasi ankle sports activity score, UCLA, and AOFAS scales were evaluated in both groups. There was no significant difference between the groups concerning activity levels, participation in sports activities, and scores of 88. However, new data analyzing return to sports and activity level has arrived from articles that studied newer generations of total ankle arthroplasty. Johns et al. systematically reviewed the current literature on this topic. This study gathered 12 papers capable of reaching inclusion criteria compounding 1270 patients (347 AA / 923) with a mean age of 59.2 years, a mean follow-up of 54.2 months, and comparable demographics 89. They found that the mean preoperative activity participation rate was 41% in the TAR cohort. However, they improved to 59% after TAR, whereas the preoperative activity participation rate of 73% was similar to the postoperative rate of 70% in the AA cohort. The most commonly reported pre and postoperative sports following AA were low-impact activities such as cycling, swimming, hiking, and dancing 89. On the other hand, while TAR's preoperative sports were similar, the most frequent postoperative activities included swimming, gardening, hiking, cycling/biking, dancing, and even higher-impact activities such as jogging, skiing, and martial arts 89. Other studies demonstrated a decrease in reported sports activity from 79.5% prior to the onset of debilitating pain to 68.9% postoperatively following AA, with an overall transition to less demanding sports 89. In another study, Dalat et al. compared the quality of life of 54 patients (32 TAR and 22 AA) with a mean follow-up of 52.2 months using the AOFAS, FFI score, and FAAM. They found that the overall mean athletic level FAAM sports score was significantly higher in the TAR group 86.

Complication rates between surgical interventions have also been well described in the literature. Norvell et al. compared physical and mental function, pain intensity, rates of revision surgery, and minor complications between these two procedures in a multisite prospective cohort study of 577 participants. At 24 months of the procedure, activities of daily living and SF-36 PCS scores were significantly higher in the TAR group than in the AA group. Furthermore, the crude incidence risks of revision surgery, complications, and success rate after adjusting for age, sex, and BMI were not statistically different between groups 79. Fanelli et al. supported this finding while performing an updated meta-analysis of the existing literature about outcomes, quality of life, and complications among persons that received AA or TAR as a treatment for end-stage ankle OA. The authors reported 21 studies, including 18,448 patients, suitable to be analyzed and found that patients undergoing TAR had a significantly greater postoperative range of motion and AOS scores. The two procedures' total complication rate was similar, including the incidence of reoperations 90.

Finally, it is crucial to consider that the existing literature on the topic needs more conclusive evidence to support the notion that participation in particular sports has a meaningful correlation with implant failure, degree of wear, or revision rates. Furthermore, Naal et al. demonstrated no association between patients' activity and the appearance of radiographic periprosthetic radiolucency during their follow-up. Also, a systematic review by Hörterer et al. did not demonstrate evidence that participation in sports results in increased failure rates of TAR 89. Table 3 summarizes the level of physical activity and type of sports performed by patients with ankle OA, TAR and AA.

	Ankle OA	**TAR**	**AA**
Sport Activity (Overall %) 89 Valderrábano et al. 52 Usuelli et al. 43 Dalat 86 Schuh 88	**54.4%** 36% 8%	**18 to 20% more** 56% 37% 68.6±25.2% 76%	**3 to 10% less** 59.8±30.0 75%
Tendency of activity 75, 89		Equal or higher demanding sports	Lower demanding sports
Most common reported sports preoperatively (Halasi score) 89, 91		3-4 cycling, swimming, hiking	3-4 cycling, swimming, hiking
Most common reported sports postoperatively (Halasi score) 89, 91		3-7 swimming, hiking, cycling, dancing, jogging, skiing, martial arts	3-4 cycling, swimming, hiking

Table 3. Comparison of physical activity and sports performance between ankle AO, TAR and AA. (ns= no significant difference)

Conclusions

Ankle OA is a painful, debilitating disease associated with multiple biomechanical changes around the lower limb. Consequently, it affects the physical activity and global performance of the persons that suffer from it. This population is young and increasing compared to osteoarthritis in other parts of the body. That is why the need to address this problem with the best available solution is of paramount importance for the global well-being of the patient.

While AA has been placed as the classical treatment option for this pathology, newer studies have shown multiple disadvantages of this surgery compared to TAR. This includes changes in the hip joint biomechanics, increased stress in the remaining hindfoot joints, higher stress in metatarsal bones, and alteration in balance and physical performance. On the other hand, newer TAR implants have been associated with standard mechanics of the lower limb, better physical and mental outcomes, higher participation and degree of sports activity, and more patients resuming sports after surgery. Moreover, these parameters have been linked with superior reported global outcomes and quality of life. Furthermore, complications, including reoperation associated with both surgical options, are equivalent.

TAR patients followed strictly by an experienced surgeon can expect better physical, mental, and quality-of-life outcomes than with other surgical options. Moreover, they can look to maintain or even increase their physical activity without increased risk of implant wear or failure. Because of this, TAR should be considered a first-line treatment for end-stage ankle OA.

Bibliografía

1. Valderrabano V, Horisberger M, Russell I, Dougall H & Hintermann B. Etiology of ankle osteoarthritis. Clinical Orthopaedics and Related Research 2009 467 1800–1806. (https://doi.org/10.1007/s11999-008-0543-6)
2. Saltzman CL, Salamon ML, Blanchard GM, Huff T, Hayes A, Buckwalter JA, Amendola A. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. Iowa Orthop J. 2005;25:44–46.
3. Barg A, Pagenstert GI, Hügle T, Gloyer M, Wiewiorski M, Henninger HB, Valderrabano V. Ankle osteoarthritis: etiology, diagnosis, and classification. Foot Ankle Clin. 2013 Sep;18(3):411-26. doi: 10.1016/j.fcl.2013.06.001. Epub 2013 Jul 24. PMID: 24008208.
4. Herrera-Pérez M, Valderrabano V, Godoy-Santos A, de César Netto C, González-Martín D & Tejero S. Ankle osteoarthritis: comprehensive review and treatment algorithm proposal. EFORT Open Reviews 2022 7 448–459. (https://doi.org/10.1530/EOR-21-0117://doi.org/10.1530/EOR-21-0117)
5. Kim H, Chung E, Lee BH. A Comparison of the Foot and Ankle Condition between Elite Athletes and Non-athletes. J Phys Ther Sci. 2013 Oct;25(10):1269-72. doi: 10.1589/jpts.25.1269. Epub 2013 Nov 20. PMID: 24259773; PMCID: PMC3820170.
6. Lee HH, Chu CR. Clinical and Basic Science of Cartilage Injury and Arthritis in the Football (Soccer) Athlete. Cartilage. 2012 Jan;3(1 Suppl):63S-8S. doi: 10.1177/1947603511426882. PMID: 26069610; PMCID: PMC4297167.
7. Bestwick-Stevenson T, Ifesemen OS, Pearson RG, Edwards KL. Association of Sports Participation With Osteoarthritis: A Systematic Review and Meta-Analysis. Orthop J Sports Med. 2021 Jun 14;9(6):23259671211004554. doi: 10.1177/23259671211004554. PMID: 34179201; PMCID: PMC8207281.
8. Paget LDA, Aoki H, Kemp S, et al. Ankle osteoarthritis and its association with severe ankle injuries, ankle surgeries and health-related quality of life in recently retired professional male football and rugby players: a cross-sectional observational study. BMJ Open 2020;10:e036775. doi:10.1136/ bmjopen-2020-036775
9. Kotsifaki A, Korakakis V, Graham-Smith P, Sideris V, Whiteley R. Vertical and Horizontal Hop Performance: Contributions of the Hip, Knee, and Ankle. Sports Health. 2021 Mar;13(2):128-135. doi: 10.1177/1941738120976363. Epub 2021 Feb 9. PMID: 33560920; PMCID: PMC8167345.
10. Lafontaine D. Three-dimensional kinematics of the knee and ankle joints for three consecutive push-offs during ice hockey skating starts. Sports Biomech. 2007 Sep;6(3):391-406. doi: 10.1080/14763140701491427. PMID: 17933200.
11. Upjohn T, Turcotte R, Pearsall DJ, Loh J. Three-dimensional kinematics of the lower limbs during forward ice hockey skating. Sports Biomech. 2008 May;7(2):206-21. doi: 10.1080/14763140701841621. PMID: 18610773.

12. Kuijt MT, Inklaar H, Gouttebarge V, Frings-Dresen MH. Knee and ankle osteoarthritis in former elite soccer players: a systematic review of the recent literature. J Sci Med Sport. 2012 Nov;15(6):480-7. doi: 10.1016/j.jsams.2012.02.008. Epub 2012 May 8. PMID: 22572082.
13. Al-Mahrouqi M, MacDonald D, PT, Vicenzino B, Smith M. Physical impairments in adults with ankle osteoarthritis: A systematic review and meta-analysis. Journal of Orthopaedic & Sports Physical Therapy. 2018 48 429-515. https:///doi/10.2519/jospt.2018.7569
14. Smith, Michelle & Al Mahrouqi, Munira & MacDonald, D. & Vicenzino, Bill. (2019). Radiological, physical and psychological features of ankle OA: A cross sectional study. Journal of Science and Medicine in Sport. 22. S18. 10.1016/j.jsams.2019.08.165.
15. Al Mahrouqi MM, MacDonald DA, Vicenzino B, Smith MD. Quality of life, function and disability in individuals with chronic ankle symptoms: a cross-sectional online survey. J Foot Ankle Res. 2020 Nov 16;13(1):67. doi: 10.1186/s13047-020-00432-w. PMID: 33198773; PMCID: PMC7667748.
16. Al-Mahrouqi MM, Vicenzino B, MacDonald DA, Smith MD. Disability, Physical Impairments, and Poor Quality of Life, Rather Than Radiographic Changes, Are Related to Symptoms in Individuals With Ankle Osteoarthritis: A Cross-sectional Laboratory Study. J Orthop Sports Phys Ther. 2020 Dec;50(12):711-722. doi: 10.2519/jospt.2020.9376. PMID: 33256512.
17. Saltzman CL, Zimmerman B, O'Rourke M, Brown TD, Buckwalter JA, Johnston R. 594 Impact of comorbidities on the measurement of health in patients with ankle 595 osteoarthritis. J. Bone Joint Surg. Am. 2006;88A:2366-2372.
18. Daniels T, Thomas R. Etiology and biomechanics of ankle arthritis. Foot Ankle Clin. 2008;13(3):341-vii.
19. Drawer S, Fuller CW. Propensity for osteoarthritis and lower limb joint pain in retired professional soccer players. Br J Sports Med. 2001;35(6):402-408.
20. Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont PJ, Jr. The epidemiology of ankle sprains in the United States. J Bone Joint Surg Am. 2010;92(13):2279-2284.
21. Kolar M, Brulc U, Stražar K, Drobnič M. Patient-reported joint status and quality of life in sports-related ankle disorders and osteoarthritis. Int Orthop. 2021 Apr;45(4):1049-1055. doi: 10.1007/s00264-020-04747-y. Epub 2020 Sep 17. PMID: 32944803.
22. Brodsky JW, Kane JM, Coleman S, Bariteau J, Tenenbaum S. Abnormalities of gait caused by ankle arthritis are improved by ankle arthrodesis. Bone Joint J. 2016 Oct;98-B(10):1369-1375. doi: 10.1302/0301-620X.98B10.37614. PMID: 27694591.
23. Valderrabano V, Nigg BM, von Tscharner V, Stefanyshyn DJ, Goepfert B, Hintermann B. Gait analysis in ankle osteoarthritis and total ankle replacement. Clin Biomech (Bristol, Avon). 2007 Oct;22(8):894-904. doi: 10.1016/j.clinbiomech.2007.05.003. Epub 2007 Jul 2. PMID: 17604886.
24. Wikstrom, Erik & Anderson, Robert & Hubbard -Turner, Tricia. (2015). Posttraumatic Ankle Osteoarthritis Alters Stair Ascent and Descent Kinetics. International Journal of Athletic Therapy and Training. 20. 37-43. 10.1123/ijatt.2015-0033.
25. Hale SA, Hertel J. Reliability and Sensitivity of the Foot and Ankle Disability Index in Subjects With Chronic Ankle Instability. J Athl Train. 2005 Mar;40(1):35-40. PMID: 15902322; PMCID: PMC1088343.
26. Yeowell G, Samarji RA, Callaghan MJ. An exploration of the experiences of people living with painful ankle osteoarthritis and the non-surgical management of this condition. Physiotherapy. 2021 Mar;110:70-76. doi: 10.1016/j.physio.2020.04.008. Epub 2020 May 8. PMID: 32713738.
27. Smith MD, Rhodes J, Al Mahrouqi M, MacDonald DA, Vicenzino B. Balance is impaired in symptomatic ankle osteoarthritis: A cross-sectional study. Gait Posture. 2021 Oct;90:61-66. doi: 10.1016/j.gaitpost.2021.08.002. Epub 2021 Aug 5. PMID: 34399156.
28. Hubbard TJ, Hicks-Little C, Cordova M. Mechanical and sensorimotor implications with ankle osteoarthritis. Arch Phys Med Rehabil. 2009 Jul;90(7):1136-41. doi: 10.1016/j.apmr.2008.11.020. PMID: 19577026.

29. Lobet S, Hermans C, Bastien GJ, Massaad F, Detrembleur C. Impact of ankle osteoarthritis on the energetics and mechanics of gait: the case of hemophilic arthropathy. Clin Biomech (Bristol, Avon). 2012 Jul;27(6):625-31. doi: 10.1016/j.clinbiomech.2012.01.009. Epub 2012 Feb 29. PMID: 22381586.
30. McDaniel G, Renner JB, Sloane R, Kraus VB. Association of knee and ankle osteoarthritis with physical performance. Osteoarthritis Cartilage. 2011 Jun;19(6):634-8. doi: 10.1016/j.joca.2011.01.016. Epub 2011 Feb 19. PMID: 21310252; PMCID: PMC3097285.
31. Rivera, Jessica & Wenke, Joseph & Ficke, James & Johnson, Anthony. (2013). Post-Traumatic OA: Unique implications for the military. Lower Extremity Review. 43-46.
32. Schmitt D, Vap A, Queen RM. Effect of end-stage hip, knee, and ankle osteoarthritis on walking mechanics. Gait Posture. 2015 Sep;42(3):373-9. doi: 10.1016/j.gaitpost.2015.07.005. Epub 2015 Jul 17. PMID: 26213184.
33. Wiewiorski M, Dopke K, Steiger C, Valderrabano V. Muscular atrophy of the lower leg in unilateral post traumatic osteoarthritis of the ankle joint. Int Orthop. 2012 Oct;36(10):2079-85. doi: 10.1007/s00264-012-1594-6. Epub 2012 Jun 22. PMID: 22722542; PMCID: PMC3460092.
34. Wikstrom EA, Anderson RB. Alterations in gait initiation are present in those with posttraumatic ankle osteoarthritis: a pilot study. J Appl Biomech. 2013 Jun;29(3):245-52. doi: 10.1123/jab.29.3.245. Epub 2012 Jul 6. PMID: 22813884.
35. Lam KC, Marshall AN, Snyder Valier AR. Patient-Reported Outcome Measures in Sports Medicine: A Concise Resource for Clinicians and Researchers. J Athl Train. 2020 Apr;55(4):390-408. doi: 10.4085/1062-6050-171-19. Epub 2020 Feb 7. PMID: 32031883; PMCID: PMC7164564.
36. Golightly YM, Devellis RF, Nelson AE, Hannan MT, Lohmander LS, Renner JB, Jordan JM. Psychometric properties of the foot and ankle outcome score in a community-based study of adults with and without osteoarthritis. Arthritis Care Res (Hoboken). 2014 Mar;66(3):395-403. doi: 10.1002/acr.22162. PMID: 24023029; PMCID: PMC4211630.
37. Morssinkhof ML, Wang O, James L, van der Heide HJ, Winson IG. Development and validation of the Sports Athlete Foot and Ankle Score: an instrument for sports-related ankle injuries. Foot Ankle Surg. 2013 Sep;19(3):162-7. doi: 10.1016/j.fas.2013.02.001. Epub 2013 Mar 25. PMID: 23830163.
38. Witteveen AG, Hofstad CJ, Breslau MJ, Blankevoort L, Kerkhoffs GM. The impact of ankle osteoarthritis. The difference of opinion between patient and orthopedic surgeon. Foot Ankle Surg. 2014 Dec;20(4):241-7. doi: 10.1016/j.fas.2014.05.008. Epub 2014 Jun 9. PMID: 25457659.
39. Alanazi SA, Vicenzino B, Rhodes J, Smith MD. Outcome measures in clinical studies of ankle osteoarthritis: a systematic review. Physiotherapy. 2022 Sep 6:S0031-9406(22)00090-6. doi: 10.1016/j.physio.2022.08.008. Epub ahead of print. PMID: 36243563.
40. Madeley NJ, Wing KJ, Topliss C, Penner MJ, Glazebrook MA, Younger AS. Responsiveness and validity of the SF-36, Ankle Osteoarthritis Scale, AOFAS Ankle Hindfoot Score, and Foot Function Index in end stage ankle arthritis. Foot Ankle Int. 2012 Jan;33(1):57-63. doi: 10.3113/FAI.2012.0057. PMID: 22381237.
41. Barg A, Wimmer MD, Wiewiorski M, Wirtz DC, Pagenstert GI, Valderrabano V. Total ankle replacement—indications, implant designs, and results. Dtsch Arztebl Int 2015; 111: 177-84. DOI: 10.3238/arztebl.2015.0177
42. Queen R. Directing clinical care using lower extremity biomechanics in patients with ankle osteoarthritis and ankle arthroplasty. J Orthop Res. 2017 Nov;35(11):2345-2355. doi: 10.1002/jor.23609. Epub 2017 Jun 16. PMID: 28543369.
43. Usuelli FG, Pantalone A, Maccario C, Guelfi M, Salini V. Sports and Recreational Activities following Total Ankle Replacement. Joints. 2017 Jun 5;5(1):12-16. doi: 10.1055/s-0037-1601408. PMID: 29114624; PMCID: PMC5672856.

44. Naal FD, Impellizzeri FM, Loibl M, Huber M, Rippstein PF. Habitual physical activity and sports participation after total ankle arthroplasty. Am J Sports Med. 2009 Jan;37(1):95-102. doi: 10.1177/0363546508323253. Epub 2008 Sep 18. PMID: 18801943.
45. Naal FD, Impellizzeri FM, Rippstein PF. Which are the most frequently used outcome instruments in studies on total ankle arthroplasty? Clin Orthop Relat Res. 2010 Mar;468(3):815-26. doi: 10.1007/s11999-009-1036-y. Epub 2009 Aug 12. PMID: 19672670; PMCID: PMC2816756.
46. Bonnin MP, Laurent JR, Casillas M. Ankle function and sports activity after total ankle arthroplasty. Foot Ankle Int. 2009 Oct;30(10):933-44. doi: 10.3113/FAI.2009.0933. PMID: 19796586.
47. McConnell EP, Queen RM. Correlation of Physical Performance and Patient-Reported Outcomes Following Total Ankle Arthroplasty. Foot Ankle Int. 2017 Feb;38(2):115-123. doi: 10.1177/1071100716672656. Epub 2016 Oct 3. PMID: 27698178.
48. Oliver SM, Coetzee JC, Nilsson LJ, Samuelson KM, Stone RM, Fritz JE, Giveans MR. Early Patient Satisfaction Results on a Modern Generation Fixed-Bearing Total Ankle Arthroplasty. Foot Ankle Int. 2016 Sep;37(9):938-43. doi: 10.1177/1071100716648736. Epub 2016 May 9. Erratum in: Foot Ankle Int. 2017 Feb;38(2):232. PMID: 27162222.
49. Cho BK, An MY, Ahn BH. Comparison of Clinical Outcomes After Total Ankle Arthroplasty Between End-Stage Osteoarthritis and Rheumatoid Arthritis. Foot Ankle Int. 2021 May;42(5):589-597. doi: 10.1177/1071100720979923. Epub 2021 Feb 9. PMID: 33557617.
50. Raikin SM, Sandrowski K, Kane JM, Beck D, Winters BS. Midterm Outcome of the Agility Total Ankle Arthroplasty. Foot Ankle Int. 2017 Jun;38(6):662-670. doi: 10.1177/1071100717701232. Epub 2017 May 2. PMID: 28462686.
51. Casartelli, N.C., Item-Glatthorn, J.F., Bizzini, M. *et al.* Differences in gait characteristics between total hip, knee, and ankle arthroplasty patients: a six-month postoperative comparison. *BMC Musculoskelet Disord* 14, 176 (2013). https://doi.org/10.1186/1471-2474-14-176.
52. Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Hintermann B. Sports and recreation activity of ankle arthritis patients before and after total ankle replacement. Am J Sports Med. 2006 Jun;34(6):993-9. doi: 10.1177/0363546505284189. Epub 2006 Feb 1. PMID: 16452268.
53. Macaulay AA, Van Valkenburg SM, DiGiovanni CW. Sport and activity restrictions following total ankle replacement: A survey of orthopaedic foot and ankle specialists. Foot Ankle Surg. 2015 Dec;21(4):260-5. doi: 10.1016/j.fas.2015.01.014. Epub 2015 Feb 18. PMID: 26564728.
54. Easley ME, Adams SB Jr, Hembree WC, DeOrio JK. Results of total ankle arthroplasty. J Bone Joint Surg Am. 2011 Aug 3;93(15):1455-68. doi: 10.2106/JBJS.J.00126. PMID: 21915552.
55. Steineman BD, Quevedo González FJ, Sturnick DR, Deland JT, Demetracopoulos CA, Wright TM. Biomechanical evaluation of total ankle arthroplasty. Part I: Joint loads during simulated level walking. J Orthop Res. 2021 Jan;39(1):94-102. doi: 10.1002/jor.24902. Epub 2020 Nov 11. PMID: 33146417; PMCID: PMC7749051.
56. Quevedo González FJ, Steineman BD, Sturnick DR, Deland JT, Demetracopoulos CA, Wright TM. Biomechanical evaluation of total ankle arthroplasty. Part II: Influence of loading and fixation design on tibial bone-implant interaction. J Orthop Res. 2021 Jan;39(1):103-111. doi: 10.1002/jor.24876. Epub 2020 Oct 20. PMID: 33030768; PMCID: PMC7748995.
57. Wu WL, Su FC, Cheng YM, Huang PJ, Chou YL, Chou CK. Gait analysis after ankle arthrodesis. Gait Posture. 2000 Feb;11(1):54-61. doi: 10.1016/s0966-6362(99)00049-1. PMID: 10664486.
58. van der Plaat LW, van Engelen SJ, Wajer QE, Hendrickx RP, Doets KH, Houdijk H, van Dijk CN. Hind- and Midfoot Motion After Ankle Arthrodesis. Foot Ankle Int. 2015 Dec;36(12):1430-7. doi: 10.1177/1071100715593913. Epub 2015 Jul 9. PMID: 26160385.

59. Shah NS, Umeda Y, Suriel Peguero E, Erwin JT, Laughlin R. Outcome Reporting in Total Ankle Arthroplasty: A Systematic Review. J Foot Ankle Surg. 2021 Jul-Aug;60(4):770-776. doi: 10.1053/j.jfas.2021.02.003. Epub 2021 Mar 4. PMID: 33766479.
60. Morasiewicz P, Dejnek M, Kulej M, Dragan SŁ, Konieczny G, Krawczyk A, Urbański W, Orzechowski W, Dragan SF, Pawik Ł. Sport and physical activity after ankle arthrodesis with Ilizarov fixation and internal fixation. Adv Clin Exp Med. 2019 May;28(5):609-614. doi: 10.17219/acem/80258. PMID: 30079998.
61. Fram B, Corr DO, Rogero RG, Pedowitz DI, Tsai J. Short-Term Complications and Outcomes of the Cadence Total Ankle Arthroplasty. Foot Ankle Int. 2022 Mar;43(3):371-377. doi: 10.1177/10711007211043853. Epub 2021 Sep 22. PMID: 34549617.
62. Rajan L, Kim J, Cronin S, Cororaton A, Day J, Gagne O, Henry J, Deland J, Demetracopoulos C, Ellis SJ. Retrospective Comparison of Midterm Survivorship, Radiographic, and Clinical Outcomes of the INBONE II and Salto Talaris Total Ankle Arthroplasty Systems. Foot Ankle Int. 2022 Nov;43(11):1419-1423. doi: 10.1177/10711007221114136. Epub 2022 Aug 24. PMID: 36000242.
63. Beyaert C, Sirveaux F, Paysant J, Molé D, André JM. The effect of tibio-talar arthrodesis on foot kinematics and ground reaction force progression during walking. Gait Posture. 2004 Aug;20(1):84-91. doi: 10.1016/j.gaitpost.2003.07.006. PMID: 15196525.
64. van Engelen SJ, Wajer QE, van der Plaat LW, Doets HC, van Dijk CN, Houdijk H. Metabolic cost and mechanical work during walking after tibiotalar arthrodesis and the influence of footwear. Clin Biomech (Bristol, Avon). 2010 Oct;25(8):809-15. doi: 10.1016/j.clinbiomech.2010.05.008. Epub 2010 Jun 22. PMID: 20573430.
65. Donelan JM, Kram R, Kuo AD. Mechanical work for step-to-step transitions is a major determinant of the metabolic cost of human walking. J Exp Biol. 2002 Dec;205(Pt 23):3717-27. doi: 10.1242/jeb.205.23.3717. PMID: 12409498.
66. Waters RL, Barnes G, Husserl T, Silver L, Liss R. Comparable energy expenditure after arthrodesis of the hip and ankle. J Bone Joint Surg Am. 1988 Aug;70(7):1032-7. PMID: 3403571.
67. Fuchs S, Sandmann C, Skwara A, Chylarecki C. Quality of life 20 years after arthrodesis of the ankle. A study of adjacent joints. J Bone Joint Surg Br. 2003 Sep;85(7):994-8. doi: 10.1302/0301-620x.85b7.13984. PMID: 14516034.
68. Morrey BF, Wiedeman GP Jr. Complications and long-term results of ankle arthrodeses following trauma. J Bone Joint Surg Am. 1980 Jul;62(5):777-84. PMID: 7391101.
69. Coester LM, Saltzman CL, Leupold J, Pontarelli W. Long-term results following ankle arthrodesis for post-traumatic arthritis. J Bone Joint Surg Am. 2001 Feb;83(2):219-28. doi: 10.2106/00004623-200102000-00009. PMID: 11216683.
70. Schaap, E.J., Huy, J. & Tonino, A.J. Long-term results of arthrodesis of the ankle. International Orthopaedics 14, 9–12 (1990). https://doi.org/10.1007/BF00183355
71. Schaap EJ, Huy J, Tonino AJ. Long-term results of arthrodesis of the ankle. Int Orthop. 1990;14(1):9-12. doi: 10.1007/BF00183355. PMID: 2341221.
72. Kennedy JG, Harty JA, Casey K, Jan W, Quinlan WB. Outcome after single technique ankle arthrodesis in patients with rheumatoid arthritis. Clin Orthop Relat Res. 2003 Jul;(412):131-8. doi: 10.1097/01.blo.0000071755.41516.a0. PMID: 12838063.
73. Lynch AF, Bourne RB, Rorabeck CH. The long-term results of ankle arthrodesis. J Bone Joint Surg Br. 1988 Jan;70(1):113-6. doi: 10.1302/0301-620X.70B1.3339041. PMID: 3339041.
74. Vertullo CJ, Nunley JA. Participation in sports after arthrodesis of the foot or ankle. Foot Ankle Int. 2002 Jul;23(7):625-8. doi: 10.1177/107110070202300707. PMID: 12146773.
75. Kerkhoff YRA, Keijsers NLW, Louwerens JWK. Sports Participation, Functional Outcome, and Complications After Ankle Arthrodesis: Midterm Follow-up. Foot Ankle Int. 2017 Oct;38(10):1085-1091. doi: 10.1177/1071100717717221. Epub 2017 Jul 14. PMID: 28708946.

76. Kerkhoff YRA, Kosse NM, Louwerens JWK. Short term results of the Mobility Total Ankle System: Clinical and radiographic outcome. Foot Ankle Surg. 2016 Sep;22(3):152-157. doi: 10.1016/j.fas.2015.06.004. Epub 2015 Jun 20. PMID: 27502222.
77. H. Rouhani, X. Crevoisier, J. Favre, K. Aminian,Outcome evaluation of ankle osteoarthritis treatments: Plantar pressure analysis during relatively long-distance walking. Clinical Biomechanics. Volume 26, Issue 4,2011,Pages 397-404. ISSN 0268-0033 https://doi.org/10.1016/j.clinbiomech.2010.11.011.
78. Thomas RH, Daniels TR. Ankle arthritis. J Bone Joint Surg Am. 2003 May;85(5):923-36. doi: 10.2106/00004623-200305000-00026. PMID: 12728047.
79. Norvell DC, Ledoux WR, Shofer JB, Hansen ST, Davitt J, Anderson JG, Bohay D, Coetzee JC, Maskill J, Brage M, Houghton M, Sangeorzan BJ. Effectiveness and Safety of Ankle Arthrodesis Versus Arthroplasty: A Prospective Multicenter Study. J Bone Joint Surg Am. 2019 Aug 21;101(16):1485-1494. doi: 10.2106/JBJS.18.01257. PMID: 31436657; PMCID: PMC7001770.
80. Valderrabano V, Nigg BM, von Tscharner V, Stefanyshyn DJ, Goepfert B, Hintermann B. Gait analysis in ankle osteoarthritis and total ankle replacement. Clin Biomech (Bristol, Avon). 2007 Oct;22(8):894-904. doi: 10.1016/j.clinbiomech.2007.05.003. Epub 2007 Jul 2. PMID: 17604886.
81. Segal AD, Cyr KM, Stender CJ, Whittaker EC, Hahn ME, Orendurff MS, Ledoux WR, Sangeorzan BJ. A three-year prospective comparative gait study between patients with ankle arthrodesis and arthroplasty. Clin Biomech (Bristol, Avon). 2018 May;54:42-53. doi: 10.1016/j.clinbiomech.2018.02.018. Epub 2018 Mar 5. PMID: 29550642.
82. Sanders AE, Kraszewski AP, Ellis SJ, Queen R, Backus SI, Hillstrom H, Demetracopoulos CA. Differences in Gait and Stair Ascent After Total Ankle Arthroplasty and Ankle Arthrodesis. Foot Ankle Int. 2021 Mar;42(3):347-355. doi: 10.1177/1071100720965144. Epub 2020 Nov 16. PMID: 33198507.
83. Wang Y, Wong DW, Tan Q, Li Z, Zhang M. Total ankle arthroplasty and ankle arthrodesis affect the biomechanics of the inner foot differently. Sci Rep. 2019 Sep 16;9(1):13334. doi: 10.1038/s41598-019-50091-6. PMID: 31527781; PMCID: PMC6746773.
84. Saltzman CL, Kadoko RG, Suh JS. Treatment of isolated ankle osteoarthritis with arthrodesis or the total ankle replacement: a comparison of early outcomes. Clin Orthop Surg. 2010 Mar;2(1):1-7. doi: 10.4055/cios.2010.2.1.1. Epub 2010 Feb 4. PMID: 20190994; PMCID: PMC2824089.
85. Sangeorzan BJ, Ledoux WR, Shofer JB, Davitt J, Anderson JG, Bohay D, Coetzee JC, Maskill J, Brage M, Norvell DC. Comparing 4-Year Changes in Patient-Reported Outcomes Following Ankle Arthroplasty and Arthrodesis. J Bone Joint Surg Am. 2021 May 19;103(10):869-878. doi: 10.2106/JBJS.20.01357. PMID: 33983146.
86. Dalat F, Trouillet F, Fessy MH, Bourdin M, Besse JL. Comparison of quality of life following total ankle arthroplasty and ankle arthrodesis: Retrospective study of 54 cases. Orthop Traumatol Surg Res. 2014 Nov;100(7):761-6. doi: 10.1016/j.otsr.2014.07.018. Epub 2014 Oct 11. PMID: 25306302.
87. Jastifer J, Coughlin MJ, Hirose C. Performance of total ankle arthroplasty and ankle arthrodesis on uneven surfaces, stairs, and inclines: a prospective study. Foot Ankle Int. 2015 Jan;36(1):11-7. doi: 10.1177/1071100714549190. Epub 2014 Sep 8. PMID: 25201334.
88. Schuh R, Hofstaetter J, Krismer M, Bevoni R, Windhager R, Trnka HJ. Total ankle arthroplasty versus ankle arthrodesis. Comparison of sports, recreational activities and functional outcome. Int Orthop. 2012 Jun;36(6):1207-14. doi: 10.1007/s00264-011-1455-8. Epub 2011 Dec 16. PMID: 22173565; PMCID: PMC3353091.
89. Johns WL, Sowers CB, Walley KC, Ross D, Thordarson DB, Jackson JB, Gonzalez TA. Return to Sports and Activity After Total Ankle Arthroplasty and Arthrodesis: A Systematic Review. Foot Ankle Int. 2020 Aug;41(8):916-929. doi: 10.1177/1071100720927706. Epub 2020 Jun 5. PMID: 32501110.

90. Fanelli D, Mercurio M, Castioni D, Sanzo V, Gasparini G, Galasso O. End-stage ankle osteoarthritis: arthroplasty offers better quality of life than arthrodesis with similar complication and re-operation rates-an updated meta-analysis of comparative studies. Int Orthop. 2021 Sep;45(9):2177-2191. doi: 10.1007/s00264-021-05053-x. Epub 2021 May 4. PMID: 33944980.
91. Halasi T, Kynsburg A, Tállay A, Berkes I. Development of a new activity score for the evaluation of ankle instability. Am J Sports Med. 2004 Jun;32(4):899-908. doi: 10.1177/0363546503262181. PMID: 15150035.
92. Mørup-Petersen A, Skou ST, Holm CE, Holm PM, Varnum C, Krogsgaard MR, Laursen M, Odgaard A. Measurement properties of UCLA Activity Scale for hip and knee arthroplasty patients and translation and cultural adaptation into Danish. Acta Orthop. 2021 Dec;92(6):681-688. doi: 10.1080/17453674.2021.1977533. Epub 2021 Sep 17. PMID: 34530681; PMCID: PMC8635665.
93. Norvell DC, Shofer JB, Hansen ST, Davitt J, Anderson JG, Bohay D, Coetzee JC, Maskill J, Brage M, Houghton M, Ledoux WR, Sangeorzan BJ. Frequency and Impact of Adverse Events in Patients Undergoing Surgery for End-Stage Ankle Arthritis. Foot Ankle Int. 2018 Sep;39(9):1028-1038. doi: 10.1177/1071100718776021. Epub 2018 May 31. PMID: 29852755; PMCID: PMC6318122.
94. Esparragoza L, Vidal C, Vaquero J. Comparative study of the quality of life between arthrodesis and total arthroplasty substitution of the ankle. J Foot Ankle Surg. 2011 Jul-Aug;50(4):383-7. doi: 10.1053/j.jfas.2011.03.004. Epub 2011 May 4. PMID: 21536459.