ISSN 2218-5836 (online)

World Journal of *Orthopedics*

World J Orthop 2020 April 18; 11(4): 206-251

Published by Baishideng Publishing Group Inc

World Journal of Orthopedics

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World Journal of Orthopedics

Volume 11 Number 4 April 18, 2020

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INDEXING/ABSTRACTING

The *WJO* is now abstracted and indexed in PubMed, PubMed Central, Emerging Sources Citation Index (Web of Science), Scopus, China National Knowledge Infrastructure (CNKI), China Science and Technology Journal Database (CSTJ), and Superstar Journals Database.

RESPONSIBLE EDITORS FOR THIS ISSUE

Responsible Electronic Editor: *Yan-Xia Xing*

Proofing Production Department Director: *Xiang Li*

NAME OF JOURNAL
World Journal of Orthopedics

ISSN
ISSN 2218-5836 (online)

LAUNCH DATE
November 18, 2010

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Bao-Gan Peng

EDITORIAL BOARD MEMBERS
http://www.wjgnet.com/2218-5836/editorialboard.htm

EDITORIAL OFFICE
Ruo-Yu Ma, Director

PUBLICATION DATE
April 18, 2020

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ONLINE SUBMISSION
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World Journal of Orthopedics

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World J Orthop 2020 April 18; 11(4): 206-212

DOI: 10.5312/wjo.v11.i4.206

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Case Control Study

Role of shoulder gradient in the pathogenesis of rotator cuff tears

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Author contributions: Sobhani Eraghi A designed research; Hajializade M and Abdollahi Kordkandi S and Shekarchizadeh E performed research; Shekarchizadeh E analyzed data; Hajializade M and Sobhani Eraghi A wrote the paper.

Institutional review board statement: This study was reviewed and approved by the Ethics Committee of Iran University of Medical Sciences under code of IR.IUMS.FMD.REC 1396.9423715006

Informed consent statement: The patients provided written consent before participation in the study.

Conflict-of-interest statement: The authors of this article declare no conflict of interest to disclose.

Data sharing statement: All data requests should be submitted to the corresponding author for consideration. Access to anonymised data may be granted following review.

STROBE statement: The authors have read the STROBE Statement-checklist of items, and the manuscript was prepared according to the STROBE Statement-checklist of items.

Open-Access: This article is an open-access article that was selected by an in-house editor and

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Abstract

BACKGROUND

Shoulder gradient has been associated with shoulder pathologies such as shoulder impingement syndrome.

AIM

To investigate if there is an association between shoulder gradient and incidence of rotator cuff tear (RCT).

METHODS

A total of 61 patients with a confirmed diagnosis of RCT were included in this retrospective study. The anteroposterior radiograph of the shoulder was used to measure shoulder gradient in adduction and neutral rotation positions. The pain level was assessed with the visual analog scale for pain.

RESULTS

The mean age of the patients was 55.7 ± 12.3 years. The mean visual analog scale of the patients was 4.1 ± 1.2. The mean shoulder gradient was 14.11° ± 2.65° for the affected shoulder and 15.8° ± 2.2° for the unaffected shoulders. This difference was not statistically significant (P = 0.41). A difference of 1.15° ± 1.82° was found between the injured and non-injured shoulder. No significant association was found between the gradient difference of the shoulder and demographic and clinical characteristics of the patients.

CONCLUSION

Shoulder gradient is not associated with the pathology of RCT. Yet, future studies with more standardization and a larger sample size are needed to investigate the role of shoulder gradient in RCT pathogenesis further.

Key words: Shoulder; Shoulder gradient; Rotator cuff tear; Pathogenesis; Anatomy

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Core tip: Shoulder anatomical characteristics have been associated with several shoulder

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Manuscript source: Unsolicited manuscript

Received: September 17, 2019
Peer-review started: September 17, 2019
First decision: December 23, 2019
Revised: January 15, 2020
Accepted: February 8, 2020
Article in press: February 8, 2020
Published online: April 18, 2020

P-Reviewer: Anand A, Pavone V
S-Editor: Dou Y
L-Editor: A
E-Editor: Liu MY

pathologies. We hypothesized that the shoulder gradient might be regarded as an anatomic factor affecting the occurrence of rotator cuff pathologies. Our analysis revealed no association between shoulder gradient and incidence of rotator cuff tear.

Citation: Sobhani Eraghi A, Hajializade M, Shekarchizadeh E, Abdollahi Kordkandi S. Role of shoulder gradient in the pathogenesis of rotator cuff tears. *World J Orthop* 2020; 11(4): 206-212
URL: https://www.wjgnet.com/2218-5836/full/v11/i4/206.htm
DOI: https://dx.doi.org/10.5312/wjo.v11.i4.206

INTRODUCTION

Rotator cuff tear (RCT) is one of the most common causes of shoulder pain and disability among the adult population the prevalence of which increases with age. In this respect, either a partial or a complete RCT has been identified in the magnetic resonance imaging (MRI) of 54% of the asymptomatic patients aged 60 years and older[1]. According to the study of Rincón-Hurtado *et al*[2], 72% of patients with rotator cuff injuries reported poor quality of life in the physical health component and 60% in the mental health component. The high prevalence of RCT also imposes a considerable financial burden on both the patients and health-care systems[3]. In this dilemma, the identification of RCT risk factors could be considered as a preventive intervention capable of reducing the health and financial burden of RCT[4].

To date, many investigations have focused on the predictors of RCT, and several risk factors have been introduced. In this regard, older age, hand dominance, and a history of trauma have been frequently associated with the risk of rotator cuff tear[5,6]. Yet, more studies are required for further identification of RCT risk factors[6].

Schamberger stated that the spine malalignment could weaken the passive support for the humerus, thereby increasing the gravity traction force on the capsule and rotator cuff muscles and causing shoulder injuries such as supraspinatus tendinitis and the shoulder impingement syndrome[7].

The height of both shoulders in the standing position generally reveals slight differences, known as shoulder gradient. Kim *et al*[8] aimed to find an association between the shoulder gradient and shoulder impingement syndrome. Based on their results, a significantly higher frequency of shoulder impingement syndrome was observed on the side of the relatively lower shoulder[8].

Based on the earlier evidence, we hypothesized that the shoulder gradient might also predispose the incidence of RCT and be regarded as an RCT risk factor. In this study, we aimed to find how the shoulder gradient is associated with the frequency of RCT.

MATERIALS AND METHODS

This study was approved by the institutional review board of Iran University of Medical Sciences, and written consent was obtained from the patients before their participation. In a cross-sectional study, 61 patients, who were referred to our orthopedic clinic from March 2017 to March 2018 in order to confirm their RCT, were included. The most eligible criteria were the diagnosis of small complete rotator cuff tear based on the MRI findings of the affected side. The MRI of the other side was intact. Patients with over 70 years of age and history of operative treatment of either side of the shoulder were excluded from the study. Associated injury, tumoral lesion, shoulder instability, and patient with a history of shoulder dislocation were excluded from the study, as well. Finally, a total number of 61 patients (total; 462 patients) were identified as eligible for the study.

With the position of the patient in 10 cm apart between the both of the medial malleoli, their heels placed in a neutral position and the knees in full extension, the anteroposterior radiograph of the shoulder was used to measure shoulder gradient in adduction and neutral rotation position of both shoulders. Both shoulders were imaged on one cassette. The gradient difference between affected and unaffected shoulders was measured at the angle between the vertical line and a line connecting a superior angle with an inferior angle of the scapula (Figure 1). The shoulder gradient was independently assessed by a musculoskeletal radiologist and an orthopedist. In

case of a discrepancy between the two observers, a consensus was achieved with the help of a third observer (an orthopedist).

Demographic characteristics of the patients such as age, gender, and body mass index and clinical characteristics of the patients such as the level of pain, etiology of injury and duration of symptoms were recorded. The pain level was assessed with the visual analog scale for pain.

Statistical analysis

SPSS for Windows, version 16, was used for statistical evaluations. Descriptive statistics were presented as mean ± SD or number and percentage. A Kolmogorov–Smirnov test was implemented to test the normality of variables. A paired *t* or its nonparametric counterpart (Wilcoxon signed-rank test) was used to compare the gradient of the shoulders. A χ^2 was used for testing the association between categorical variables. Pearson's correlation coefficient test was used for the evaluation of potential correlations. A median split approach was used for the categorization of quantitative variables. $P < 0.05$ was considered a significant statistical value.

RESULTS

The study population included 31 females and 30 males with a mean age of 55.7 ± 12.3 years. The injury was dominant in 39 (64%) of the patients. Trauma was the most frequent etiology of the RCT in our patients. The mean visual analog scale of the patients was 4.1 ± 1.2. The mean symptom duration was 4.57 ± 1.88 mo. The clinic demographic characteristics of the patients are demonstrated in detail in Table 1.

The mean shoulder gradient was 14.95° ± 2.1°. The mean shoulder gradient was 14.11° ± 2.65° for the affected shoulder and 15.8° ± 2.2° for the unaffected shoulders. Accordingly, a difference of 1.15° ± 1.82° was found between the injured and non-injured shoulder. This difference was not statistically significant, by the way (P = 0.41). The median shoulder gradient was 14.1. The median shoulder gradient was 13.94° affected shoulders and in 14.6° in unaffected shoulders. This difference was not statistically significant, as well (P = 0.12).

No significant association was found between the difference of shoulder gradient and demographic characteristics of the patients such as age, gender, and body mass index. Moreover, no significant association was found between the difference of shoulder gradient and clinical variables such as etiology and symptom duration (Table 2). The shoulder gradient was not correlated with the pain level of the patients (r = 0.109, P = 0.071). The shoulder gradient was not correlated with other clinical and demographic characteristics of the patients, as well.

DISCUSSION

In this study, we aimed to find how the shoulder gradient is associated with the incidence of RCT. According to our results, the mean shoulder gradient was not significantly different between the affected and unaffected shoulder of RCT patients. Moreover, the distribution of shoulder gradient was not significantly different between the injured and non-injured shoulder. No significant association was also found between the clinicodemographic characteristics of the patients and the shoulder gradient difference, as well.

RCTs are amongst the most frequent shoulder pathologies that might significantly reduce the quality of life of the affected patients. Thus, considerable interest has been focused on the optimization of its therapeutic approaches and the identification of its risk factors as well[5,9].

Traditionally, the normal population is known to have balanced shoulders, and any disturbance in this balance is considered pathologic like the scapular tumoral lesion[10]. However, recent studies reveal that contrary to popular belief, shoulder balance often does not exist in a healthy population. Akel *et al*[11] found an average height difference of 7.5 ± 5.8 mm between the shoulders of the normal population. In addition, the average coracoid height difference was 6.9 ± 5.8 mm. The clavicular angle, the clavicle–rib cage intersection, and clavicular tilt angle were also different between the shoulders of healthy individuals[11]. Acromial morphology has also been associated with rotator cuff tear pathology in several investigations[12-14]. The study of Cherchi *et al*[15] also revealed that the critical shoulder angle is significantly greater RCT patients. According to these findings, they suggested that an anatomical difference seems to exist between RCT patients and the general population[15]. We hypothesized that the

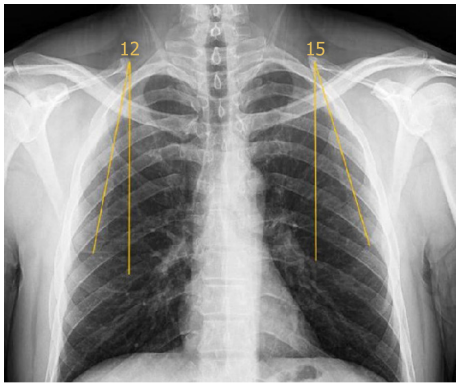

Figure 1 The gradient difference between affected and unaffected shoulders.

shoulder gradient might also be regarded as an anatomic factor affecting the occurrence of rotator cuff pathologies.

Naidoo *et al*[16] evaluated the shoulder slope in 260 posterior radiographs of the shoulder to provide an appropriate definition of the shoulder slope with standardized anatomical landmarks. Based on their results, the mean shoulder slope was approximately 13.56° ± 3.70°. They also found a significant association between the age and shoulder slope, that is to say larger slopes were observed in older ages[16]. By contrast, we did not find any significant association between the shoulder gradient and clinicodemographic characteristics of the patients. Yet, it should be noted that their method of slope evaluation was different from ours.

Although different industries such as the textile and aviation industries have reported the shoulder gradient in accordance with the specific occupational activities, the association of shoulder slope with shoulder pathologies has been merely investigated[16-18].

In one of the few articles in this field, Kim *et al*[8] investigated the association of shoulder gradient with acromiohumeral interval of both shoulders in patients with unilateral shoulder impingement syndrome. They used an angulometer to measure the shoulder gradient. According to their results, the frequency of shoulder impingement syndrome was considerably more on the side of the relatively lower shoulder (76.2%). This study was the first and only study suggesting the role of shoulder gradient in shoulder pathologies[8].

We did not find a significant association between the shoulder gradient and RCT. Yet, the results of this study might be adversely affected by several confounding factors. We did not take into account factors that might play a role in shoulder levels, such as the lengths of the lower extremities and the level of the pelvic bone. Moreover, the sample size of this study was not large enough to perform a multivariate analysis and reduce the effect of confounding factors. Thus, future standardized studies with larger sample sizes are recommended to fully untie the role of shoulder gradient in shoulder pathologies such as RCT.

Table 1 Clinical and demographic characteristics of the patients with rotator cuff problems

Variable	mean ± SD /*n* (%) (*n* = 61)
Age (yr)	55.7 ± 12.3
Gender	
Female	31 (50.8)
Male	30 (49.2)
BMI (kg/m^2)	27.3 ± 4.9
Dominancy	
Dominant	39 (64)
Non-dominant	22 (36)
Etiology	
Trauma	33 (54.1)
Rheumatologic disorders	18 (25.5)
Unspecified	10 (16.4)
Type of RCT	
Supraspinatus	27 (43.5)
Supraspinatus and infraspinatus	21 (34.5)
Subscapularis	5 (8.5)
Supraspinatus and subscapularis	8 (13.5)
Symptom duration (mo)	4.57 ± 1.88
VAS pain	4.1 ± 1.2

BMI: Body mass index; VAS pain: Visual analogue scale for pain; RCT: Rotator cuff tear.

Table 2 The statistical association of shoulder gradient with the clinical and demographic characteristics of the patients with rotator cuff problems

Variable	Shoulder gradient difference (*n* = 61)	*P* value
Age (yr)		0.089
< 60	-1.48 ± 1.08	
> 60	-1.03 ±0.96	
Gender		0.12
Female	-1.1 ± 0.77	
Male	-1.21 ± 0.97	
BMI (kg/m^2)		0.11
< 26	-1.53 ± 0.89	
> 26	-1.27± 1.07	
Dominancy		0.092
Dominant	-1.25 ± 1.09	
Non-dominant	-1.27 ± 1.11	
Etiology		0.068
Trauma	-1.47 ± 1.21	
Rheumatologic disorders	-1.12 ± 1.28	
Unspecified	-1.52 ± 1.03	
Type of RCT		0.51
Supraspinatus	-1.13 ± 1.4	
Supraspinatus and infraspinatus	-1.28 ± 1.33	
Subscapularis	-1.09 ± 1.1	
Supraspinatus and subscapularis	-1.22 ± 1.39	
Symptom duration (mo)		0.77
< 3	-1.61 ± 1.12	
> 3	-1.16 ± 1.09	
VAS pain		0.14
< 3	-1.52 ± 1.02	

> 3	-1.24 ± 0.95

BMI: Body mass index; VAS pain: Visual analogue scale for pain.

ARTICLE HIGHLIGHTS

Research background

Rotator cuff tear (RCT) is referred to the injury of one or more of the tendons or muscles of the rotator cuff and is known as one of the most common causes of shoulder pain and disability among the adult population. Identification of risk factors, which predisposes the incidence of RCT, is of considerable importance in the prevention of such injuries.

Research motivation

Earlier investigations have revealed an association between shoulder gradient and shoulder pathologies, such as shoulder impingement syndrome. We hypothesized that the shoulder gradient might also predispose the occurrence of RCT.

Research objectives

In this study, we evaluated the association between the shoulder gradient and RCT incidence to find whether the shoulder gradient could be regarded as a risk factor for RCT or not.

Research methods

Sixty-one patients with a confirmed diagnosis of RCT were identified as eligible for the study. On the anteroposterior radiograph of the shoulder, we evaluated the gradient of both shoulders in adduction and neutral rotation positions. The gradient difference between affected and unaffected shoulders was also calculated.

Research results

The mean shoulder gradient was 14.11° ± 2.65° for the affected shoulder and 15.8° ± 2.2° for the unaffected shoulders. Based on these results, a gradient difference of 1.15° ± 1.82° was found between the injured and non-injured shoulders. This difference was not statistically significant (P = 0.41). The shoulder gradient was not correlated with the pain level of the patients (r = 0.109, P = 0.071), as well as with other clinical and demographic characteristics of the patients.

Research conclusions

Based on the results of this study, there is no association between the shoulder gradient and incidence of RCT. Moreover, the shoulder gradient is not associated with the pain level of RCT patients.

Research perspectives

Future large-scale studies allowing the elimination of confounding factors in a multivariate analysis will shed more light on the role of shoulder gradient in the incidence of RCT.

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World Journal of Orthopedics

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World J Orthop 2020 April 18; 11(4): 213-221

DOI: 10.5312/wjo.v11.i4.213

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Cohort Study

Day case *vs* inpatient total shoulder arthroplasty: A retrospective cohort study and cost-effectiveness analysis

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Author contributions: Borakati A contributed to the design, data collection, analysis and wrote the manuscript; Nagaraj C and Gadikoppula S assisted with design of the study and data collection; Ali A and Kurer M reviewed the manuscript.

Institutional review board statement: This study was registered with the local clinical governance department at North Middlesex University Hospital as a service evaluation. No formal research ethics committee opinion was sought for this retrospective study with no alteration to patient care.

Informed consent statement: No informed consent was necessary for publication of anonymised results of this local service evaluation in line with local policies.

Conflict-of-interest statement: The authors confirm that there are no known conflicts of interest associated with this publication.

Data sharing statement: No additional data are available.

STROBE statement: The authors have read the STROBE checklist of items, and the manuscript was prepared and revised according to the STROBE checklist of items.

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Abstract

BACKGROUND

Day case total shoulder arthroplasty (TSA) is a novel approach, not widely practiced in Europe. We conducted a retrospective cohort study of patients comparing elective day case and inpatient TSAs in our United Kingdom centre.

AIM

To evaluate the efficacy and cost-effectiveness of day case TSA compared to standard inpatient total shoulder arthroplasty.

METHODS

All patients undergoing TSA between January 2017 and July 2018 were included. Outcome measures were: Change in abduction and extension 3 mo postoperatively; 30-d postoperative adverse events and re-admissions in day case and inpatient groups. We also conducted an economic evaluation of outpatient arthroplasty. Multivariate linear and logistic regression were used to adjust for demographic and operative covariates.

RESULTS

Fifty nine patients were included, 18 d cases and 41 inpatients. There were no adverse events or re-admissions at 30 d postoperatively in either group. There were no significant differences in adjusted flexion (mean difference 16.4, 95%CI: 17.6-50.5, $P = 0.337$) or abduction (mean difference: 13.2, 95%CI: 18.4-44.9, $P = 0.405$) postoperatively between groups. Median savings with outpatient arthroplasty were £529 (interquartile range: 247.33-789, $P < 0.0001$).

CONCLUSION

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Manuscript source: Unsolicited manuscript

Received: November 11, 2019
Peer-review started: November 11, 2019
First decision: December 5, 2019
Revised: February 24, 2020
Accepted: March 12, 2020
Article in press: March 12, 2020
Published online: April 18, 2020

P-Reviewer: Paschos NK, Li JM
S-Editor: Zhou JJ
L-Editor: A
E-Editor: Liu MY

Day case TSA is a safe, effective procedure, with significant cost benefit. Wider use may be warranted in the United Kingdom and beyond, with potential for significant cost savings and improved efficiency.

Key words: Orthopedics; Shoulder; Arthroplasty; Ambulatory care; Day case; Cohort studies

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Core tip: In this article we show that day case total shoulder arthroplasty is a feasible, safe and effective alternative to inpatient admission for the same procedure, with an associated average cost saving of £529.

Citation: Borakati A, Ali A, Nagaraj C, Gadikoppula S, Kurer M. Day case *vs* inpatient total shoulder arthroplasty: A retrospective cohort study and cost-effectiveness analysis. *World J Orthop* 2020; 11(4): 213-221
URL: https://www.wjgnet.com/2218-5836/full/v11/i4/213.htm
DOI: https://dx.doi.org/10.5312/wjo.v11.i4.213

INTRODUCTION

Total shoulder arthroplasty is well established as a safe, effective treatment for multiple pathologies, including osteoarthritis, rotator cuff arthropathy and complex fractures of the humerus[1,2].

Typically, it is performed under general anaesthesia with an overnight stay for administration of analgesia intravenously. Increasingly, however, the procedure is performed on an outpatient (or day case) basis. This has been facilitated through the use of continuous nerve blockade with portable infusion devices for ambulatory analgesia outside of the hospital setting[3].

The latter approach has been widely adopted across the United States[4,5], although uptake has been slow elsewhere, notably in the United Kingdom and Europe, with limited literature available. There is a significant potential for improved cost effectiveness and throughput efficiency with an outpatient approach. We have therefore conducted this retrospective cohort study in our United Kingdom centre with the aim of comparing the clinical and cost efficacy of traditional inpatient total shoulder arthroplasty with outpatient regimens in this setting. We hypothesised that our outpatient protocol would have equivalent efficacy to inpatient protocols with a significantly lower cost.

MATERIALS AND METHODS

Inclusion criteria

All adult (18+) patients undergoing elective total shoulder arthroplasty at North Middlesex University Hospital, London, United Kingdom between January 2017 and July 2018 were included. Both anatomical and reverse arthroplasties were included.

Exclusion criteria

Patients undergoing arthroplasty for an acute traumatic indication, such as fracture, were excluded.

Perioperative procedure

Prior to selection for surgery all patients underwent clinical assessment of mobility with range of motion recorded. All patients selected for surgery underwent anaesthetic pre-assessment and were identified based on pre-morbid status (no severe cardiorespiratory co-morbidities) for suitability for an outpatient procedure. Patients must have had a friend or family member staying with them for 24 h postoperatively, speak English, be contactable by telephone and have the family member willing to be trained to remove the analgesic catheter. Patients eligible for outpatient arthroplasty only underwent day case analgesic procedure and same day discharge dependent on staffing availability.

All patients were admitted on the day of surgery and operated on under general anaesthesia. Patients selected for a day case procedure were given a continuous intrascalene analgesic infusion following the surgery and discharged the same day, with the infusion pump *in situ*. This was then removed at day 3 postoperatively in the community by family members or friends of the patient who were given written instructions on removal. Patients were followed up daily over telephone by specialist pain nurses until removal of the infusion catheter. Those with planned inpatient stays were given strong opiate analgesia and were admitted until this could be weaned off with appropriate mobilisation as assessed by physiotherapy. Patients were followed up at 3 mo postoperatively to assess mobility and to assess imaging to ensure appropriate prosthesis placement.

Data collection

Data was collected retrospectively, with patients identified from prospectively recorded theatre logs and case note retrieval. Data collected included demographic information such as age and gender, co-morbidities and indication for procedure, operative information and postoperative complications and range of motion at 3 mo as assessed in clinic. Patients were stratified into day case and inpatient groups depending on the preoperative plan for admission or not.

Outcomes

Primary outcome measures were mean increase in active flexion and abduction at 3 mo postoperatively. Secondary outcomes were postoperative complication and re-admission rates at 30 d.

Economic analysis

The difference in costs between day case and inpatient procedures was calculated using the cost of catheter insertion, analgesic infusion costs and removal of the catheter for the outpatient group. For the inpatient group the median length of stay was used to calculate cost of inpatient nursing care. All other costs of care were assumed equal in both groups.

The median cost difference between inpatient and outpatient groups was calculated and statistical significance assessed using the Mann Whitney *U* test.

Statistical analysis

Descriptive data are presented as means with standard deviation or medians with interquartile ranges (IQR) dependent on the normality of the data as appropriate. Normality was assessed by visual inspection of histograms and quantile-quantile plots and subsequent statistical testing was directed by this assessment. Statistical significance in terms of demographic and operative differences between day case and inpatient groups was calculated using Fisher's exact or Student's two-tailed *t*-tests as appropriate.

Difference in mean abduction and flexion between inpatient and outpatient groups was assessed using Student's two-tailed *t*-test. The threshold for statistical significance was set with $P < 0.05$.

Multivariate linear and logistic regression analysis was used to adjust for demographic and operative covariates (including age, gender, side, anatomic *vs* reverse and indication of procedure) in the primary outcomes, following univariate analysis.

Statistical analysis was conducted using Microsoft R Open 3.5.1[6] (Microsoft Corp., Redmond, WA, United States) with tidyverse[7], desctools[8], finalfit[9], tableone[10] and lubridate[11] packages.

Following the main analysis we later decided (post-hoc) to conduct an analysis of the power of our sample to detect a clinically significant difference (agreed by consensus of the study team) of 30 degrees of abduction between outpatient and inpatient groups. This analysis used the variance in abduction following total shoulder arthroplasty at 6 mo as reported by Ramzjou *et al*[12].

Reporting guidelines

This study is reported according to the STROBE guidelines for observational studies[13].

RESULTS

Fifty nine eligible patients were identified in the study period, of these, 18 were planned day cases and 41 planned inpatient stays. The characteristics of the study population are summarised in Table 1, note- all the planned day case patients were

discharged on the day of surgery as expected and all inpatients were admitted overnight as planned. Inpatients had a median stay of 2 d and 6 h (IQR: 28-78 h). There were no significant differences in day case and inpatient groups at baseline.

Unadjusted analysis (Table 2) showed no significant difference between groups for the increase in range of motion postoperatively. Univariate analysis of the demographic and operative covariates, alongside admission status is displayed in Table 3, there were no significant associations between the primary outcomes and the explanatory variables.

Following adjustment for all covariates (Table 3 and Figure 1), there was no significant difference between day case and inpatient groups for change in flexion (mean difference: 16.4, 95%CI: 17.6-50.5, P = 0.337) and abduction postoperatively (mean difference: 13.2, 95%CI: 18.4-44.9, P = 0.405).

There were no adverse events related to surgery in both groups and no re-admissions following discharge in either group.

Economic analysis

Mean cost of admission was £260 per day. This gave a median cost of admission for the inpatient group of £585 (IQR: 303.33-845). Cost of catheter insertion, infusion and removal was £56. Cost of the analgesia catheter was the same for all outpatients. It is assumed all other variables are the same between inpatient and outpatient groups.

The median savings of outpatient arthroplasty were therefore £529 (IQR: 247.33-789.00, P < 0.0001).

Power calculation

Post-hoc power calculations showed with this sample size, there was a 0.861 power to detect a 30 degree difference in abduction using the variance reported by Razmjou *et al*[12] at 6 mo.

DISCUSSION

This study is the only published experience of outpatient total shoulder arthroplasty in the United Kingdom. We show the non-inferiority of day case total shoulder replacement with inpatient total shoulder arthroplasty in terms of range of motion and adverse events postoperatively, at lower cost.

Our results mirror those reported elsewhere. Ilfield *et al*[3] showed similar range of motion outcomes in inpatient and outpatient groups in their initial pilot study with a single intrascalene block postoperatively in 2005. In their follow up randomised trial they further showed patients who did not have the block, had a lower range of motion initially after the operation as would be expected, despite high doses of intravenous opioids[14].

Recently, Bean *et al*[15] in their similarly sized retrospective study in the United States, showed reduced 90-d complication rates with outpatient arthroplasty and fewer visits to emergency departments following discharge compared to their inpatient comparator. In this study, patients were excluded from receiving outpatient surgery if they had a number of comorbidities, such as cardiopulmonary disease. Leroux *et al*[4] and Basques *et al*[5] in their population level studies in the United States also confirmed no increased adverse events or re-admissions in those undergoing outpatient surgery, even after adjusting for pre-existing co-morbidities and demographic factors such as age.

The cost benefit of outpatient shoulder arthroplasty has already been modelled in the United States, where savings were estimated between 747 and $15507 per patient, with a base case of $5594[16]. Our findings match the lower end of these estimates, however, we have only evaluated two key variables for cost differential in our analysis. Additional analgesics, blood tests and physiotherapy costs are likely to increase the relative cost of standard inpatient arthroplasty and we have not accounted for these. Further, admission costs in the United States are known to be markedly higher than the United Kingdom[17].

In addition to direct costs, the potential for increased throughput and reduction of bed use is significant, particularly in the context of the National Health Service where there are significant waiting times and targets to be met.

Our study is also relatively unique in having solely remote follow up of patients with the infusion catheter. Many centers have specialist community nursing teams to facilitate the care and monitoring of the analgesic infusion whilst in the community. Our study shows that it is safe to monitor these patients remotely, while alleviating the need for specialist community nursing resources and training.

In the United Kingdom the only published experience of nerve block infusions for ambulatory shoulder surgery was a successful pilot of 10 patients, which showed

Table 1 Summary characteristics of study population

Characteristic	Day case	Inpatients	*P* value
n	18	41	
Age [mean (SD)]	70.9 (11.1)	71.7 (8.53)	0.758
Male (%)	4 (22.2)	11 (26.8)	0.960
Right side (%)	10 (55.6)	27 (65.9)	0.645
Reverse (%)	15 (83.3)	34 (82.9)	1.000
Mean preoperative flexion [degrees (SD)]	43.2 (25.9)	57.9 (30.1)	0.079
Mean preoperative abduction [degrees (SD)]	52.6 (27.7)	53.9 (27.4)	0.883
Indications			
Glenohumeral arthritis (%)	8 (44.4)	17 (41.4)	1.000
Rotator cuff tendonitis (%)	9 (50.0)	17 (41.4)	0.580
Rotator cuff tear (%)	10 (55.6)	13 (31.7)	0.146
Length of stay [median (IQR)]	N/A	2 d 6 h (27.6-78.4 h)	

Note for indications, patients may have one or more pathologies. IQR: Interquartile range; N/A: Not available.

good analgesia[18].

Strengths

Our study is relatively unique outside of the United States and has a comparator group of inpatients unlike many similar studies. We have further looked at functional outcomes in terms of range of motion in comparison to inpatient surgery unlike much of the previous literature. This study also contains the only cost analysis of outpatient shoulder arthroplasty outside the United States. We believe our study has greater applicability to the publicly provided health systems found in the United Kingdom and Europe, both in terms of demographic similarity and patient pathways.

Further, the statistical analysis we have conducted is robust and the multivariate analysis we have conducted includes several covariates which have been adjusted for. Finally, we have conducted a power calculation, which whilst post-hoc, shows that this study may be appropriately powered and can be used to inform future studies.

Limitations

We have not been able to collect data on co-morbidities to adjust for this as a covariate for postoperative results. Further we have not collected data on pain scores or satisfaction in the long term, which are key factors in the success of the operation. Further, although we have collected data on the two key movements (extension and abduction) ideally a formalised functional assessment such as the Oxford shoulder score[19] should be used. However, in theory, as the operative procedure is identical in both inpatient and outpatient groups, there should be no long term differences in pain or function with the outpatient method, which only alters the postoperative analgesia modality.

For the cost analysis we did not look at all possible costs associated with each procedure and their respective pathways but only the key differentiators, the cost of the catheter and infusion for outpatients and the cost of admission of inpatients (the latter only includes nursing costs). Preferably, alternative costs such as anaesthetic and recovery times, pain nurse telephone follow up, inpatient physiotherapy, pain nurse and medication costs should be included.

Ideally, an appropriately powered, randomized controlled trial with long term follow up comparing patients undergoing outpatient arthroplasty with a continuous nerve block *vs* the traditional inpatient group is needed, as yet, no such trial has been conducted. This trial should randomise patients regardless of pre-existing co-morbidities and assess postoperative complication rates, re-admission rates as well as postoperative function and overall service discharge rate. A comprehensive cost analysis using National Health Service tariff prices is essential following this to ensure translation in our setting.

The criterion regarding appropriate selection of patients is important, as there is much debate around this, in shoulder but also hip and knee arthroplasty, where outpatient surgery has been more extensively studied[20]. Meneghini *et al*[21] have recommended a scoring system to facilitate selection of suitable patients for day case arthroplasty, however, this only considered hip and knee arthroplasties. Ideally, a

Table 2 Unadjusted changes in flexion, abduction and discharge rates at 3 mo postoperatively in day case and inpatient groups

Characteristic	Day case	Inpatients	*P* value
n	18	41	
Post-op change in flexion (mean ± SD, degrees)	32.7 ± 52.1	48.6 ± 53.7	0.325
Post-op change in abduction (mean ± SD, degrees)	42.5 ± 47.8	33.2 ± 58.7	0.528

similar scoring system or set of criteria to identify eligible patients for day case shoulder arthroplasties is needed.

Further, it may be advantageous to use regional anaesthesia only as opposed to a general anaesthetic to further reduce recovery times and potentially to extend surgery to those unfit for general anaesthesia. This has been employed in arthroscopic procedures and some more minor shoulder surgeries such as rotator cuff repair, but is rarely used for total shoulder arthroplasty due to inadequate analgesia. Development of newer techniques such as continuous intrascalene blocks and alternative blocks such as supraclavicular blocks may ameliorate this[22].

It must be noted that the peripheral nerve block techniques that facilitate day case shoulder arthroplasty are not without their disadvantages. The process of achieving regional nerve blockade takes significantly more time than induction of general anaesthesia[23]. With intrascalene blockades, complications include pneumothoraces, phrenic nerve palsies, transient or permanent neurological deficits including hoarseness of voice and Horner's syndrome due to incorrect nerve blockade and, rarely, systemic toxicity such as myocardial depression. Overall, the risks of regional anaesthesia for surgery are still far lower and less severe than with general anaesthesia[24]. In conclusion, elective total shoulder arthroplasty appears to be safe and effective when performed as a day case procedure in the United Kingdom, with lower costs, mirroring similar results reported in the United States. This suggests that these procedures should be performed more widely as a day case procedure in the United Kingdom and other countries with similar publicly funded health systems, in carefully selected patients, to reduce bed occupancy, improve efficiency and reduce costs. However, larger, more rigorous randomised controlled trials comparing the day case procedure with traditional inpatient regimes including robust cost-effectiveness analyses are needed.

Table 3 Uni- and multi-variate analysis of postoperative range of motion differences

Explanatory variable	Univariate flexion (degrees)		Multivariate flexion (degrees)		Univariate abduction (degrees)		Multivariate abduction (degrees)	
	Mean increase (95%CI)	*P* value	Mean increase (95%CI)	*P* value	Mean increase (95%CI)	*P* value	Mean increase (95%CI)	*P* value
Day case (*vs* inpatient)	15.9 (-16.2 to 48.0)	0.325	16.4 (-17.6 to 50.5)	0.337	9.33 (-20.1 to 38.8)	0.528	13.2 (-18.4 to 44.9)	0.405
Age (increasing)	0.50 (-1.11 to 2.12)	0.534	1.71 (-0.45 to 3.88)	0.118	1.05 (-0.40 to 2.50)	0.152	1.97 (-0.03 to 3.98)	0.054
Gender (male)	-3.30 (-30.9 to 37.5)	0.848	-11.7 (-25.4 to 48.9)	0.530	5.34 (-25.9 to 36.6)	0.733	7.68 (-26.8 to 42.2)	0.657
Laterality (right)	-29.3 (-59.1 to 0.56)	0.054	-36.7 (-70.4 to -3.08)	0.033	-7.44 (-35.5 to 20.6)	0.598	-17.3 (-48.6 to 13.9)	0.271
Reverse/anato-mical	-1.76 (-41.5 to 38.0)	0.930	-16.4 (-50.4 to 17.5)	0.337	9.05 (-27.1 to 45.2)	0.618	-9.10 (-56.9 to 38.7)	0.704
Glenohumeral arthritis	-13.8 (-43.6 to 15.9)	0.357	-18.8 (-52.4 to 14.8)	0.266	-9.04 (-36.3 to 18.3)	0.510	-17.5 (-48.6 to 13.7)	0.266
Cuff tendonitis	-0.08 (-30.11 to 29.96)	0.996	-9.93 (-48.1 to 28.2)	0.603	-7.66 (-35.0 to 19.7)	0.577	-20.2 (-55.6 to 15.2)	0.256
Cuff tear	8.66 (-21.83 to 39.15)	0.572	-5.67 (-43.1 to 31.7)	0.762	6.53 (-21.3 to 34.4)	0.641	-7.69 (-42.4 to 27.0)	0.658

CI: Confidence interval.

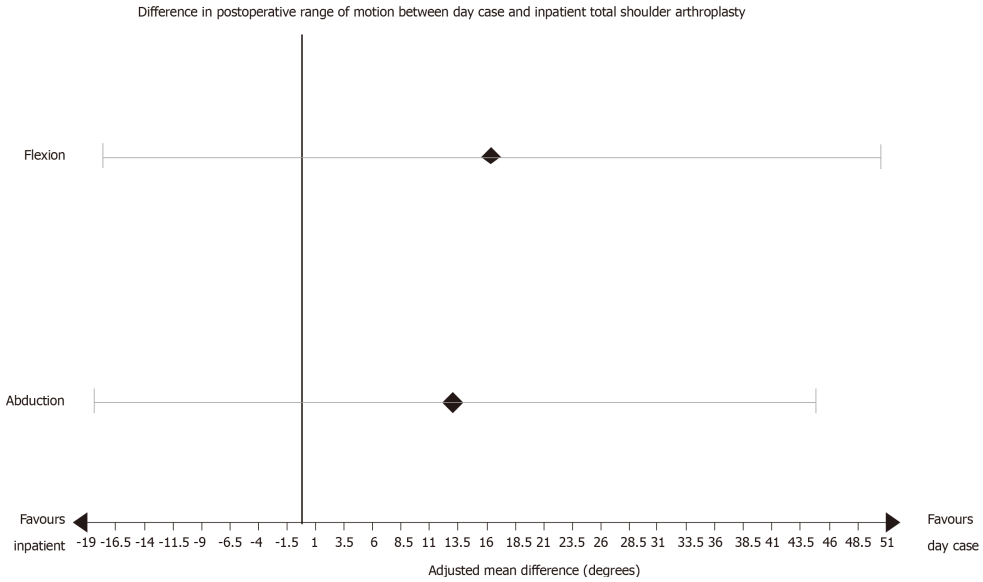

Figure 1 Adjusted mean difference in postoperative flexion and extension between day case and inpatient groups at 3 mo. Bars represent 95% confidence intervals.

ARTICLE HIGHLIGHTS

Research background

Total shoulder arthroplasty is typically performed as an inpatient procedure with an overnight stay for adequate analgesia and observation. Advances in regional anaesthesia have enabled this major operation to be conducted as an outpatient procedure. The safety, efficacy and cost-effectiveness of the outpatient procedure are well established in the United States, but evidence and experience in the techniques are lacking elsewhere.

Research motivation

Worldwide, there is significant scarcity in healthcare resources in terms of funding and bed capacity. These pressures are particularly serious in publicly funded health systems, such as that in the United Kingdom's National Health Service, where we report our experience. Performing

procedures such as total shoulder arthroplasty as outpatient procedures may reduce bed occupancy while obtaining significant cost benefits. The study was registered with our local clinical governance department as a service evaluation, no explicit patient consent was required for this study of anonymised retrospective data.

Research objectives
We aimed to compare standard inpatient total shoulder arthroplasty with outpatient total shoulder arthroplasty. The primary outcomes were change in flexion and extension at 3 mo postoperatively in each group. Adverse events, re-admission rates and cost analyses were also obtained.

Research methods
We conducted a retrospective cohort study of all patients who underwent total shoulder arthroplasty at North Middlesex University Hospital, London, United Kingdom between January 2017 and July 2018. Both inpatient and outpatient surgical groups underwent general anaesthesia and the same operative procedures. The outpatient group had continuous intrascalene analgesic infusion catheters which were retained postoperatively and they were discharged on the day of surgery. These patients were followed up by telephone by specialist community pain nurses for 3 d postoperatively and the catheter removed by the patient in their home on day 3. Costs were calculated with median length of stay and admission costs in the inpatient group and catheter, infusion and community nursing costs in the outpatient group. Between group differences were assessed using Student's *t*-test or χ^2 tests as appropriate. Multivariate linear and logistic regression was conducted to adjust for confounding variables.

Research results
Fifty nine patients were included, 18 d cases and 41 inpatients. There were no adverse events or re-admissions at 30 d postoperatively in either group. There were no significant differences in adjusted flexion (mean difference: 16.4, 95%CI: 17.6-50.5, P = 0.337) or abduction (mean difference: 13.2, 95%CI: 18.4-44.9, P = 0.405) postoperatively between groups. Median savings with outpatient arthroplasty were £529 (interquartile range: 247.33-789, P < 0.0001).

Research conclusions
This study shows that outpatient total shoulder arthroplasty is a safe procedure with similar efficacy to traditional inpatient arthroplasty. We demonstrate significant cost savings with the outpatient procedure in our publicly funded, United Kingdom setting. These findings suggest that outpatient total shoulder arthroplasty should replace traditional inpatient arthroplasty in suitable patients, in the United Kingdom and beyond, to save costs and relieve capacity.

Research perspectives
Ideally an appropriately powered, randomised control trial comparing outpatient and inpatient procedures is required to evaluate the technique. Formal functional assessment with tools such as the Oxford shoulder score is also needed to accurately assess efficacy. New methods of anaesthesia such as total regional anaesthesia with brachial plexus blockade need further study and may obviate the need for general anaesthesia and extend availability of surgery to those unfit for general anaesthesia. Novel minimally invasive surgical techniques such as arthroscopic and robotic shoulder arthroplasty may also reduce pain and the need for inpatient admission.

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World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2020 April 18; 11(4): 222-231

DOI: 10.5312/wjo.v11.i4.222

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Analysis of orthopedic surgical procedures in children with cerebral palsy

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Author contributions: All authors contributed to the study design and identified patients; Rehbein I collected the demographic data; Rehbein I, Pagano I, Teske V, and von Heideken J contributed to the data interpretation; von Heideken J performed the statistical analysis; Rehbein I, Pagano I, Teske V, and von Heideken J contributed to the manuscript preparation; Cúneo A and Pérez ME edited the manuscript.

Institutional review board statement: The study was reviewed and approved by the Centro Hospitalario Pereira Rossell Institutional Review Board.

Informed consent statement: Not applicable, this is a medical chart review.

Conflict-of-interest statement: The authors declare no conflicts of interest.

Data sharing statement: No additional data are available.

Open-Access: This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution

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Abstract

BACKGROUND

Orthopedic surgery in children with cerebral palsy (CP) aims to improve function and prevent deformities. Each child's condition in CP is unique and many co-variables influence surgical decision-making including a patient's age and their functional level. Little is known about the frequency of different types of orthopedic surgery in children with CP who have varied functional levels, particularly in countries from Latin America.

AIM

To assess the type of orthopedic surgical procedures in relation to age and gross motor function in children with CP.

METHODS

This retrospective study included all children with CP (*n* = 245) treated with elective orthopedic surgery at a Uruguayan university hospital between October 2010 and May 2016 identified from a surgical database. Eighteen children (7%) were lost to follow-up due to missing medical charts. Demographics, gross motor function classification (GMFCS), and orthopedic surgeries were obtained from the medical records of 227 children. Chi-squared tests and analysis of variance were used to assess the frequency of surgery, accounting for GMFCS levels. Mean age for soft tissue *vs* bone surgery was compared with the independent samples *t*-test.

RESULTS

A total of 711 surgical procedures were performed between 1998 and 2016. On average, children had 3.1 surgical procedures and the mean age at first surgery was 8.0 years. There were no significant differences in age at first surgery among GMFCS levels ($P = 0.47$). The most common procedures were lower leg soft tissue

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Manuscript source: Unsolicited manuscript

Received: December 10, 2019
Peer-review started: December 10, 2019
First decision: February 20, 2020
Revised: February 21, 2020
Accepted: March 12, 2020
Article in press: March 12, 2020
Published online: April 18, 2020

P-Reviewer: Emara KM
S-Editor: Gong ZM
L-Editor: Filipodia
E-Editor: Liu MY

surgery (n = 189, 27%), hip tenotomy (n = 135, 19%), and hamstring tenotomy (n = 104, 14%). For children with GMFCS level I, the mean number of surgeries per child [1.8 (range 1-9)] differed significantly at $P < 0.05$ in children with GMFCS levels II [3.2 (1-12)], III [3.2 (1-8)], IV [3.3 (1-13)], and V [3.6 (1-11)]. Within II, III, IV, and V, there was no significant difference in mean number of surgeries per child when comparing across the groups. The proportion of soft tissue surgery *vs* bone surgery was higher in GMFCS levels I-III (80%-85%) compared to levels IV (68%) and V (55%) ($P < 0.05$).

CONCLUSION

The frequency of surgical procedures per child did not increase with higher GMFCS level after level I. However, the proportion of bone surgery was higher in GMFCS levels IV-V compared to I-III.

Key words: Children; Cerebral palsy; Gross Motor Function Classification System; Surgery; Epidemiology

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Core tip: Little is known about the frequency of different types of orthopedic surgery in children with cerebral palsy, particularly in Latin America, as most studies related to orthopedic surgery are retrospective case series describing a specific surgery. This paper illustrated that among Uruguayan children with cerebral palsy, the number of corrective surgeries performed did not differ by functional motor ability (gross motor function classification levels) after level I, but the types of surgeries did differ by gross motor function classification levels. The proportion of soft tissue surgery *vs* bone surgery was higher in ambulatory children compared to non-ambulatory children.

Citation: Rehbein I, Teske V, Pagano I, Cúneo A, Pérez ME, von Heideken J. Analysis of orthopedic surgical procedures in children with cerebral palsy. *World J Orthop* 2020; 11(4): 222-231
URL: https://www.wjgnet.com/2218-5836/full/v11/i4/222.htm
DOI: https://dx.doi.org/10.5312/wjo.v11.i4.222

INTRODUCTION

Cerebral palsy (CP) is the most common neurologic disorder causing motor impairment in children and affects 2-3 of 1000 children[1]. In Uruguay, this amounts to roughly 100 children diagnosed with CP annually. CP is commonly classified not only by the dominant symptom, but by functional motor ability, according to the Gross Motor Functional Classification Scale (GMFCS)[2].

Orthopedic surgery is common in children with CP. A Danish registry study concluded that 41% of children between 8 and 15 years with GMFCS level I, 54% with level II, and 62% with levels III, IV or V had received orthopedic surgery[3]. Orthopedic surgery aims to improve the child's quality of life by controlling pain, optimizing independence and self-care, maximizing movement, balance and coordination, and maintaining functionality[4]. Another primary indication for orthopedic surgery is to prevent future complications such as contractures, hip dislocations, and scoliosis progression[5]. Each child's condition in CP is unique making it difficult to establish guidelines about when is the best age for different types of orthopedic surgery. Several factors affect the timing for a surgical procedure: the change of spasticity over time which in general is most severe in preschoolers[6], the development of joint contractions[7], hip migration[8], pain[9], the GMFCS level and comorbidities[4,7].

There is a trend towards single event multilevel surgery (SEMLS), which can be defined as two or more soft tissue or bony surgical procedures performed at two or more anatomical levels during a single surgery[10]. Avoiding repeated operations has many advantages, including fewer hospital admissions and periods of rehabilitation. Little is known about the frequency of different types of orthopedic surgery in children with CP. Most studies related to orthopedic surgery are retrospective case series describing a specific surgery. We are only aware of one published study in the

literature that has described the frequency of orthopedic surgical procedures in children with CP[11] and to the best of our knowledge, there are no studies of this kind in Latin America.

The aim of this retrospective cohort study was to analyze the frequency, anatomic location, and type of orthopedic surgical procedures in relation to age and gross motor function in children with CP. We hypothesized that the frequency of surgical procedures per child would increase with higher GMFCS level.

MATERIALS AND METHODS

Ethical considerations

Institutional Human Subjects approval was obtained for this study from our local Board (Centro Hospitelario Pereira Rossell).

Recruitment of participants

We retrospectively reviewed the charts of all patients with CP treated with orthopedic surgery at a public university hospital providing care to children of lower socioeconomic status in Montevideo between October 2010 and May 2016. Patients were identified from the hospital surgical electronic database for elective orthopedic surgery. As the surgical registry became computerized in October 2010 this date was chosen as the start date for the study. Among the 251 patients retrieved from the surgical database, 6 did not have a CP diagnosis recorded in the medical charts and were excluded. Thus, 245 patients with CP treated with orthopedic surgery were included in this study. The flow of the patients through the study is illustrated in Figure 1.

Assessment and evaluation

CP subtype was classified according to the Surveillance of Cerebral Palsy in Europe into Bilateral Spastic, Unilateral Spastic, Dyskinetic, Ataxic, and Non classifiable CP[12]. GMFCS level was established based on findings in the medical history from the treating physician or rehabilitation physician. Because this classification system was not used in our hospital from the beginning of the study period, we chose to use the last recorded GMFCS level in the medical charts. During phase one of the data collection, all orthopedic surgeries recorded in the patients' medical history were collected and confirmed by reading the surgical history in the medical chart. The type of surgery was noted, soft tissue or bone, and classified according to the most affected anatomical location as follows: Spine, upper extremity, pelvic osteotomy, proximal femur osteotomy, hip tenotomy, distal femur osteotomy, surgery for patella alta, hamstring tenotomy, osteotomy lower leg, soft tissue lower leg, and foot. Soft tissue lower leg surgery included: slide and Z lengthening of the Achilles tendon and soleus and gastrocnemius aponeurotic lengthening such as Vulpius to treat foot equinus. Orthopedic surgeries that could not be classified into this system were defined as "other" types of surgery. For example, "other" included implant removal, wound infection requiring a reoperation, or correction of cast. Bilateral procedures of the same type and on the same date were counted as one surgery. The surgical procedure with two or more soft tissue or bony surgical procedures at two or more anatomical levels during one operative procedure was classified as an SEMLS[10]. Pelvic osteotomies with proximal femur osteotomy and hip tenotomy were not classified as a single event multi-level surgery. A database was constructed using data extracted from the charts.

Statistical analysis

Descriptive statistics such as counts, percentages, means and standard deviations or medians with ranges were used to characterize the sample. Age at first surgery, surgeries per patient, and mean number of surgical sessions was compared among GMFCS levels using one-way analysis of variance (ANOVA). Number of surgeries classified by type of surgery (soft tissue and bone surgery) was compared using the chi-squared test. Mean age for soft tissue *vs* bone surgery was compared with the independent samples *t*-test. *P* values of 0.05 or less were considered statistically significant. Statistical analysis was performed with the statistical program SPSS for Mac 23.0 (www.spss.com, SPSS Inc., Chicago, IL, United States).

The statistical methods of this study were reviewed by Dr. Maura Daly Iversen, Professor of Public Health and Physical Therapy Sacred Heart University.

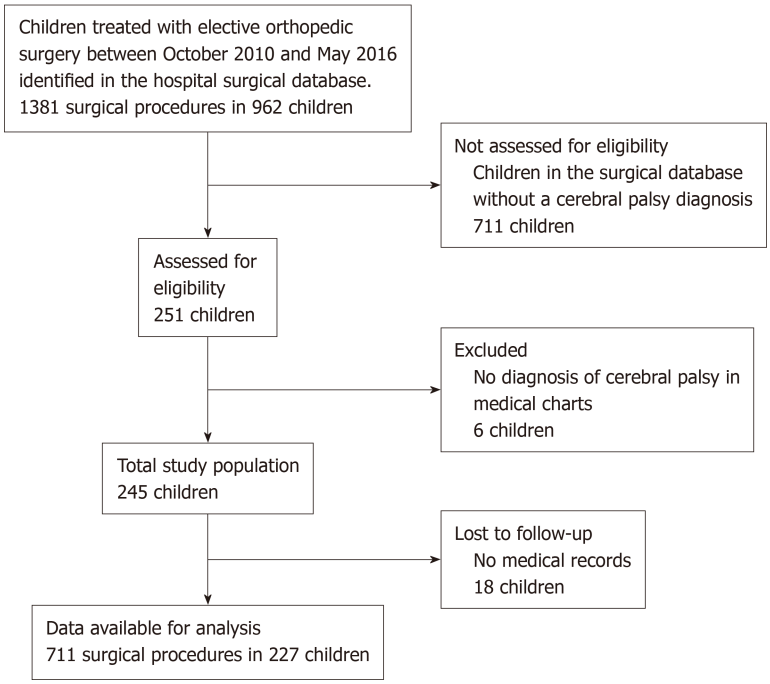

Figure 1 Flow chart of children in the study.

RESULTS

Of the 245 patients included in the study, 18 (7%) were lost due to missing charts. Thus, data on 227 patients with CP (46% female) were obtained from the medical records. The mean age of the patients at the first surgery was 8.1 years (range 2-19) and the mean follow-up from first surgery was 52 mo (range 0-219 mo). Most children were classified as having spastic diplegia (80%) or spastic hemiplegia (17%). In 1% of children, the CP subtype was not possible to classify. The proportion of children within the different GMFCS levels was I = 14%, II = 22%, III = 18%, IV = 23, and V = 23% (Table 1).

Table 2 illustrates surgical characteristics of the 227 children. There were 711 total surgical procedures performed on these children between 1998 and 2016. The mean number of surgeries per patient was 3.1 (range 1-13). An ANOVA on the mean number of surgeries per child between different GMFCS levels yielded significant variation, F (4, 222) = 3.69, P = 0.006. A post hoc Tukey test showed that for children with GMFCS level I, the mean number of surgeries per child [1.8 (range 1-9)] differed significantly at $P < 0.05$ with children with GMFCS levels II [3.2 (1-12)], III [3.2 (1-8)], IV [3.3 (1-13)], and V [3.6 (1-11)]. Within GMFCS levels II, III, IV, and V, there was no significant difference in the mean number of surgeries per child. Taken together, these results suggest that children with GMFCS level I have significantly fewer surgeries than children with more limited ability to ambulate. However, the frequency of surgical procedures per child did not increase with higher GMFCS level after level I.

The ANOVA test demonstrated no significant differences in age at first surgery among GMFCS levels [F (4, 222) = 1.71, P = 0.47]. Not including surgeries classified as other, 441 surgeries were classified as soft tissue surgery and 217 as bone surgery. The mean age for soft tissue surgery was 8.3 years compared to 11.0 years for bone surgery ($P < 0.05$). The proportion of soft tissue surgery was higher in GMFCS levels I-III (77%) compared to levels IV-V (59%) ($P < 0.05$) (Figure 2).

The total number of visits to the surgical theater for children in this study was 413. The mean number of surgeries per child was 1.8 (1-10). ANOVA on the mean number of surgeries per child between different GMFCS levels yielded no significant variation [F (4, 222) = 1.71, P = 0.149]. Of the 413 times a child was in the surgical theater, SEMLS was performed 140 times (34%) with an average of 2.6 (range 2-5) procedures. The distribution of children who underwent SEMLS based on GMFCS level was I = 5%, II = 25%, III = 26%, IV = 26%, and V = 18%.

The most common procedures performed were soft tissue surgery of lower leg [number of procedures = 189 (27%)], adductor psoas tenotomy [n = 135 (19%)], and hamstring tenotomy (n = 102 (14%)) (Table 3). Of all the surgeries, 8% were classified as other including removal of osteosynthesis material, correction of casts and in two children, surgical treatment due to post-operative infection. The most common soft

Table 1 Demographic features, cerebral palsy classification, and Gross Motor Function Classification System

Variable	Value
Mean age at first surgery, yr (range)	8.1 (2-19)
Mean age at end of study period, yr (range)	12.5 (4-27)
Female, *n* (%)	105 (46)
Cerebral Palsy subtype, *n* (%)	
Bilateral spactic	180 (80)
Unilateral spactic	38 (17)
Dyskinetic	5 (2)
Ataxic	1 (0)
Non classifiable	3 (1)
GMFCS level, *n* (%)	
I	33 (14)
II	51 (22)
III	40 (18)
IV	52 (23)
V	51 (23)

GMFCS: Gross Motor Function Classification System.

tissue surgery of the lower leg was unilateral or bilateral Vulpius (78%). In 22% of the children with soft tissue surgery of the lower extremity, the procedure was repeated 1-3 times on the same side. Hip surgery, regardless of the type, was more common in GMFCS levels IV and V. The mean age for pelvic osteotomies was 8 years (range 3-16) and hip tenotomies was 8 years (range 2-16). Among the 227 patients, hip salvage procedures were performed in 4 children (1.7% of the patients). The mean age at surgery for soft tissue lower leg, hamstring tenotomy, hip tenotomy, and pelvic osteotomy was under 10 years. The mean age at surgery was 10 years or more for foot, lower leg osteotomy, surgery for patella alta, distal femur osteotomy, proximal femur osteotomy, upper extremity surgery, and spine surgery.

DISCUSSION

Key findings

This study analyzed the frequency, anatomic location, and type of orthopedic surgical procedures in relation to age and gross motor function in children with CP in a public university hospital providing care to children of lower socioeconomic status. We hypothesized that the frequency of surgical procedures per child would increase with higher GMFCS level. This hypothesis could not be confirmed with our data, as the frequency of surgical procedures per child did not increase with higher GMFCS level after level I. This result could partly be explained by the indication and goal of the surgery in an ambulatory child, which is to improve gait, compared to the goal of surgery in a non-ambulatory child where the goal of treatment is often related to pain relief, greater comfort with positioning, improved basic care, correction of severe foot deformities, prevention of hip dislocation, and/or to halt progression of scoliosis[5]. Another reason is that the benefit of surgery in non-ambulatory children needs to be judged against the increased risk of major complications due to the presence of comorbidities such as malnutrition and decreased pulmonary and cardiac function[7]. Additionally, there is also an increased risk of complications from surgery such as nerve palsies and neuropathic pain in this patient group[5].

We identified only one published study that described the frequency of orthopedic surgical procedures in children with CP[11]. This study examined data from 127 children and only classified lower extremity surgeries. The researchers did not include children with GMFCS level V and children with hemiplegia who had isolated tendo-achilles lengthening surgery. The average age at first operation was 6.9 years compared to 8.0 years in our study. These researchers also found no significant differences among GMFCS levels for the number of procedures performed, but children at GMFCS level II underwent significantly more surgical sessions than those at level I. Since there are few data reported, it is hard to draw any conclusion about

Table 2 Surgical Features of 227 children with cerebral palsy

Variable	Value
Total number of surgeries	711
Mean number of surgeries per patient (range) by GMFCS	
I	1.8 (1-9)
II	3.2 (1-12)
III	3.2 (1-8)
IV	3.3 (1-13)
V	3.6 (1-11)
Total number of visits to the surgical theater	413
Mean number of visits to the surgical theater per patient (range)[1]	1.8 (1-10)
Mean number of visits to the surgical theater per patient (range) by GMFCS	
I	1.4 (1-5)
II	1.9 (1-6)
III	1.7 (1-4)
IV	1.8 (1-7)
V	2.1 (1-10)
Number of single event multilevel surgeries[2] (% of all visits to the surgical theater)	140 (34%)
Number of hip salvage procedures (% of patients)	4 (1.7%)
Number of deep infections (% of all surgeries not including revisions for infections)	2 (0.3%)

[1]A patient may have more than one surgery during one visit to the surgical theater;
[2]Defined as two or more soft tissue or bony surgical procedures at two or more anatomical levels during one operative procedure. Pelvic osteotomies with proximal femur osteotomy and hip tenotomy were not classified as a single event multi-level surgery. GMFCS: Gross Motor Function Classification System.

whether children in our cohort received similar numbers of surgeries compared to other parts of the world.

Few children in our study had surgery at a very young age, because in preschool children with CP, orthopedic issues are normally treated without surgery[5]. However, children with more severe forms of CP often receive adductor-psoas tenotomies at young age to prevent hip subluxation[13]. In our study, surgery among ambulatory children aged 6 to 10 years focused on limb alignment, often as SEMLS in GMFCS level higher than I. Among non-ambulatory children aged 6 to 10 years, surgery focused on prevention of hip subluxation or dislocation. Among adolescents, surgeries focus more on preventing recurrence of lower extremity deformities.

Among all surgeries performed, roughly one-third of the surgeries were SEMLS. However, the complexity of the SEMLS varied between lengthening of two tendons on two different anatomic levels and advanced surgery combining both soft tissues and bony procedures in more than two different anatomic levels.

Even though orthopedic surgery in children with CP focuses primarily on the lower extremities, one might expect a higher prevalence of upper extremity surgeries in this cohort. However, we found only three upper extremity surgeries in our data. One possible explanation for this small number of upper extremity surgeries in our study is that in Uruguay plastic surgeons are responsible for correcting wrist and hand deformities. We did not have access to these medical charts and therefore, the real number of upper extremity surgeries in our study population is probably higher.

Among the nine children in our study who had scoliosis surgery, none developed a wound infection, while Samdini *et al*[14] reported 4.7% of spine surgeries in 127 children with CP resulted in wound infections requiring re-operation. Since we did not include unplanned surgeries performed outside surgical hours (evenings and weekends), we may be under-estimating the post-operative infections requiring surgery. However, we did not find any indication of under-reporting in the medical charts.

Strengths and weaknesses of the study

As with all retrospective research, this study had several limitations. One is that it was conducted by reviewing medical charts at a single hospital including only children with at least one orthopedic surgery. Therefore, these results may have limited generalizability. Since we did not know the total number of children with CP we could not determine the incidence of orthopedic surgery in this sample of patients.

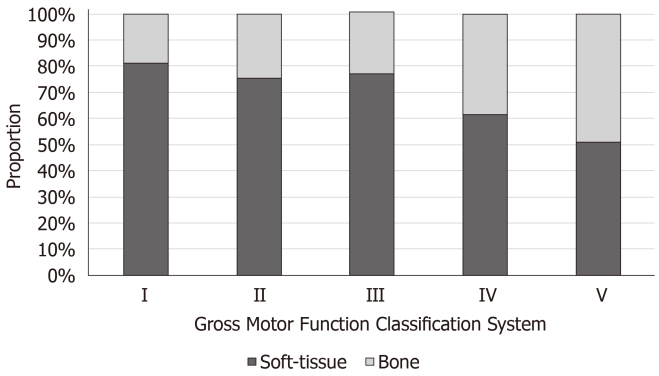

Figure 2 Proportion of soft tissue surgery (*n* = 441) *vs* bone surgery (*n* = 227) in 227 children with cerebral palsy stratified by Gross Motor Function Classification System.

Additionally, there could be patients with CP that were not registered for elective surgery with a CP diagnosis in the hospital surgical electronic database and therefore, were not included in the study. However, to minimize this selection bias, we examined medical records to determine whether any patients without a CP diagnosis had a surgical procedure that could indicate that the child had CP. We also examined medical charts of children from the neuropediatric department to identify whether any children had a CP diagnosis and could not identify any new patients with CP. The fact that 7% of the medical records could not be located demonstrates a weakness of the hospital's non-electronic medical chart archive system. This supports the advantage for functioning national databases in order to adequately follow-up regarding the outcomes of these patients. The literature strongly supports the effectiveness of specifically designed follow-up programs for the prevention of hip dislocation in children with CP[8,15,16].

There is always a risk of information bias. In this study, data could be misclassified according to CP subtype, GMFCS level, and type of surgery. To lessen the impact of misclassification, we searched the entire medical chart including radiographs. We did not analyze change in functional level over time for these children. However, the children's rehabilitation doctors also confirmed GMFCS level and CP-subtype recorded in the medical charts.

The orthopedic care of children with CP in Uruguay is carried out by both public and private institutions with approximately 50% of all orthopedic surgeries in children with CP performed at the public pediatric university hospital in Uruguay, the location of this study. There is a potential for random error due to the fact that some children might have been operated at other hospitals in Uruguay. We did not find any indication of this occurring in the medical charts. However, there is always the possibility that the children subsequently had orthopedic surgery in another hospitals outside Montevideo or changed to private health care or were transferred to an adult hospital at the age of 15 years. In this study, we did not have access to the medical charts of other hospitals. The mortality during childhood is high in GMFCS level V[17] and this is another random error that we could not adjust for in our analysis, as we could not confirm whether some of the children died during the study period.

Spasticity reduction treatment might in some cases postpone surgery[18] and we did not look at these potential confounders. Children with CP in Uruguay have limited access to botulinum toxin and selective dorsal rhizotomy. However, the access to gait analysis and spasticity reduction treatment in the form of oral Baclofen, regular physiotherapy and orthotic devices probably increased over the study period with the increased availability of rehabilitation centers like Teleton and increased resources in the health care system due to economic growth in Uruguay during the past 15 years. For example, the number of soft tissue surgeries in the lower limb to correct foot equinus might be affected by this as well as by a change in surgical technique over time.

Many co-variables beyond a patient's age and their functional level influence decision making for surgery. For example, surgical technique, accepted indications, and co-morbidities of the child. However, analyzing the different indication for surgery was beyond the scope of this paper. The indication for surgery changes over time and in the beginning of the study period very few patients had spine surgery partly due to a belief that the risk of major complication was too high. The Uruguayan health system has also changed during the study period and a higher proportion of children with CP in Uruguay are probably operated today in other non-public

Table 3 Number of orthopedic surgeries between 1998 and 2016 and average age and range at surgery in 227 children with cerebral palsy, stratified by Gross Motor Function Classification System

Type of surgery	Gross Motor Function Classification System										Total	
	I		II		III		IV		V			
	n (%)	Years (range)	*n* (%)	Years (range)	*n* (%)	Years (range)	*n* (%)	Years (range)	*n* (%)	Years (range)	*n* (%)	Years (range)
Spine	0	NA	1 (1)	10 (10-10)	1 (1)	14 (14-14)	3 (2)	11 (11-11)	5 (3)	13 (11-15)	9 (1)	13 (10-15)
Upper extremity	1 (2)	10 (10-10)	0	NA	1 (1)	10 (10-10)	1 (1)	12 (12-12)	0	NA	3 (0)	11 (10-12)
Pelvic osteotomy[1]	2 (3)	13 (12-12)	1 (1)	13 (13-13)	2 (2)	7 (6-8)	7 (4)	8 (5-13)	21 (12)	7 (3-16)	33 (5)	8 (3-16)
Proximal femur osteotomy	4 (7)	12 (7-15)	15 (9)	10 (5-15)	14 (11)	11 (5-16)	22 (13)	11 (3-20)	42 (23)	8 (1-23)	98 (14)	10 (1-23)
Hip tenotomy	4 (7)	7 (4-8)	22 (13)	7 (0-14)	31 (24)	8 (4-15)	32 (19)	8 (3-15)	46 (24)	7 (1-16)	135 (19)	8 (0-16)
Distal femur osteotomy	0	NA	6 (4)	15 (14-18)	7 (5)	13 (12-15)	18 (11)	14 (10-20)	5 (3)	15 (12-18)	36 (5)	15 (10-20)
Surgery for Patella alta	0	NA	5 (3)	16 (13-18)	2 (1)	13 (13-13)	2 (1)	12 (10-15)	0	NA	9 (1)	15 (10-18)
Hamstring tenotomy	2 (3)	11 (7-15)	22 (13)	8 (0-15)	24 (19)	7 (5-15)	33 (19)	8 (4-15)	21 (12)	8 (2-16)	102 (14)	8 (0-16)
Osteotomy lower leg	0	NA	2 (1)	10 (10-11)	1 (1)	19 (19-19)	1 (1)	10 (10-10)	0	NA	4 (1)	13 (10-19)
Soft tissue lower leg	41 (67)	8 (4-15)	65 (39)	8 (0-16)	38 (30)	8 (0-17)	32 (19)	9 (4-16)	14 (8)	7 (3-12)	189 (27)	8 (0 -17)
Foot	5 (8)	10 (7-13)	13 (8)	13 (9-17)	3 (2)	13 (12-14)	11 (7)	13 (9-16)	8 (4)	11 (2-18)	40 (6)	12 (2-18)
Other[2]	2 (3)	6 (0-13)	13 (8)	14 (7-19)	6 (5)	13 (5-21)	10 (6)	13 (8-18)	22 (12)	10 (2-18)	53 (8)	12 (0-21)
Total	61	9 (0-15)	165	10 (0-19)	130	9 (3-21)	172	10 (3-20)	183	8 (1-23)	711	9 (0-23)

[1]Associated proximal femur osteotomies are counted separately;
[2]Implant removal, reoperations due of wound infections, correction of casts. NA: Not applicable.

hospitals.

Despite these limitations this study had numerous strengths. To the best of our knowledge, this is the first study to describe the frequency of different orthopedic surgical procedures in children with CP in relation to GMFCS level and age group. It is also the first study to report the frequency of orthopedic surgical procedures performed in children with CP at a public University Clinic in Uruguay. Another strength is that the number of children in this study is large and the surgical procedures were confirmed by medical chart reviews.

In conclusion, these results suggest that children with GMFCS level I have significantly fewer surgeries than children with a more limited ability to ambulate but the frequency of surgical procedures per child did not increase with higher GMFCS level after level I. However, the proportion of soft tissue surgery was higher in GMFCS levels I-III compared to IV-V. Even though each individual's condition is unique in children with CP, information from this study may help to predict future orthopedic surgical interventions based on the GMFCS level and age and can be useful as a basis for comparison for future studies.

ARTICLE HIGHLIGHTS

Research background

Little is known about the frequency of different types of orthopedic surgery in children with cerebral palsy (CP), particularly in Latin America.

Research motivation

The aim of this retrospective cohort study was to analyze the frequency, anatomic location, and type of orthopedic surgical procedures in relation to age and gross motor function classification (GMFCS) in children with CP in a public university hospital providing care to children of lower socioeconomic status.

Research objectives

We hypothesized that the frequency of surgical procedures per child would increase with higher GMFCS level. Information from this study may help to predict future orthopedic surgical interventions based on the GMFCS level and age and can be useful as a basis for comparison for future studies.

Research methods

This retrospective study included all children with CP (n = 245) treated with elective orthopedic surgery at a Uruguayan university hospital between October 2010 and May 2016 identified from a surgical database. Demographics, GMFCS, and orthopedic surgeries were obtained from the medical records of 227 children.

Research results

This study examined surgical procedures among children with CP, with a total of 711 surgical procedures performed between 1998 and 2016. On average, children had 3.1 surgical procedures and no differences existed regarding age at first surgery. The most common procedures were: lower leg soft tissue surgery, hip tenotomy, and hamstring tenotomy. For children with GMFCS level I the mean number of surgeries per child differed significantly with children with GMFCS levels II, III, IV and V. Within II, III, IV, and V there was not a significantly significant difference of mean number of surgeries per child when comparing across the groups. The proportion of soft tissue surgery *vs* bone surgery was significantly higher in GMFCS levels I-III, compared to levels IV and V. This study provides a rich description of orthopedic procedures performed in children with CP. However, we do not know the prevalence of surgery in all patients with CP.

Research conclusions

This is to our knowledge the first study to describe the frequency of different orthopedic surgical procedures in children with CP in relation to GMFCS level and age group. Our hypothesis that the frequency of surgical procedures per child would increase with higher GMFCS level could not be confirmed with our data, as the frequency of surgical procedures per child did not increase with higher GMFCS level after level I. This result could partly be explained by the indication and goal of the surgery in an ambulatory child which is to improve gait, compared to the goal of surgery in a non-ambulatory child where the goal is often related to pain relief, greater comfort with positioning, improved basic care, correction of severe foot deformities, prevention of hip dislocation, and/or to halt scoliosis progression. Additionally, the benefit of surgery in non-ambulatory children needs to be judged against the increased risk of major complications due to the presence of comorbidities. There is also an increased risk of complications from surgery.

Research perspectives

Few studies describe the panorama of different surgical procedures used in an entire population of children with CP or investigate differences in orthopedic surgical treatment between different CP-subtypes.

ACKNOWLEDGEMENTS

We thank Professor Maura Daly Iversen for using her expertise in biostatistical analysis to review the final statistical methods used in the study. We thank Dr Magdalena Cibils and Dr Claudia Gonzalez for their contribution to the research.

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World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2020 April 18; 11(4): 232-242

DOI: 10.5312/wjo.v11.i4.232

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Total hip replacement using MINIMA® short stem: A short-term follow-up study

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Author contributions: All authors helped to perform the research; Drosos GI contribution to the manuscript writing, performing procedures, drafting conception, design and data analysis; Tottas S contribution to writing the manuscript, drafting conception and design; Kougioumtzis I contribution to writing the manuscript; Tilkeridis K contribution to writing the manuscript, performing procedures; Christos C contribution to writing the manuscript; Ververidis A contribution to writing the manuscript, performing procedures.

Institutional review board statement: This study was reviewed and approved by the Ethics Committee of the University General Hospital of Alexandroupolis.

Informed consent statement: Patients were not required to give informed consent to the study because the analysis used anonymous clinical data that were obtained after each patient agreed to treatment by written consent.

Conflict-of-interest statement: All

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Abstract

BACKGROUND

Total hip replacement has become one of the most successful orthopaedic procedures. The length of the femoral stem constitutes one of the most important geometrical and mechanical features of the prosthesis. Several different implants are currently available but data are limited concerning the clinical results for some of these implants.

AIM

To report the short-term clinical and radiological results of a novel squared section, tapered design – with four conicity - short stem in total hip replacement.

METHODS

This is a retrospective study of a prospectively collected data using of MINIMA® short stem in 61 consecutive patients with at least 1 year follow-up. The collected data included patients' demographics, type of arthritis, bone morphology, perioperative data, clinical results using Harris Hip Score, EuroQol (EQ-5D), pain score and satisfaction rate, complications and radiological results.

RESULTS

Total 61 patients were included in our study with a mean age of 56 years of age (range 25-73 years). The majority of them (68.6%) were women, thirty seven patients (56.9%) were less than 60 years of age and almost half of patients (45.1%) suffered from secondary osteoarthritis (hip dysplasia, osteonecrosis, *etc.*). The mean time of follow-up examination was 33.4 mo (2.8 years) with a range of 12-57 months (1-4.8 years). In 35 patients (56.9%) the follow-up examination was more than 3 years. No major complications such as revision, periprosthetic fracture, dislocation or infection were presented. Re-admission 90 d postoperatively or laterwas deemed unnecessary for any reason regarding the operation. Respectively, the mean pain score, mean Harris hip score, and mean EQ-5D were

authors declare no conflicts-of-interest related to this article.

Data sharing statement: No additional data are available.

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Manuscript source: Invited manuscript

Received: October 29, 2019
Peer-review started: October 29, 2019
First decision: December 12, 2019
Revised: December 19, 2019
Accepted: March 12, 2020
Article in press: March 12, 2020
Published online: April 18, 2020

P-Reviewer: Anand A, Cui Q
S-Editor: Wang JL
L-Editor: A
E-Editor: Liu MY

improved from 6.3, 58.7 and 77.3 preoperatively to 0.1, 95.1, and 79.8 postoperatively. The Satisfaction rate at the final follow-up was 9.9 (SD 0.3, range 8.0-10.0). All stems were classified as stable bone ingrowth and no radiolucent lineswere revealed in any of the modified Gruens' zone at the postoperative X-rays. Stem subsidence was within acceptable limits and the incidence of distal cortical hypertrophy was relatively low.

CONCLUSION
The clinical and radiological results concerning the MINIMA® short stem are excellent according to this first report of this specific design of the short femoral stems. Because of the small number of cases and short-term follow-up of this study, a longer follow up time and more patients' enrollment is required.

Key words: Total hip replacement; Total hip arthroplasty; Short-stem; Hip prostheses; Femoral components; MINIMA® stem

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Core tip: Total hip replacement has become one of the most successful orthopaedic procedures. The length of the femoral stem constitutes one of the most important geometrical and mechanical features of the prosthesis. Several different implants are currently available but data are limited concerning the clinical results for some of these implants. Our objective is to report the short-term results of a novel squared section, tapered design –with four conicity- short stem. According to our findings the clinical and radiological results were excellent in the short-term follow-up using the MINIMA® short stem in total hip replacement.

Citation: Drosos GI, Tottas S, Kougioumtzis I, Tilkeridis K, Chatzipapas C, Ververidis A. Total hip replacement using MINIMA® short stem: A short-term follow-up study. *World J Orthop* 2020; 11(4): 232-242
URL: https://www.wjgnet.com/2218-5836/full/v11/i4/232.htm
DOI: https://dx.doi.org/10.5312/wjo.v11.i4.232

INTRODUCTION

Total hip replacement (THR) is considered as one of the most successful procedures in orthopaedic surgery[1,2]. The length of the femoral stem is one of the most important geometrical and mechanical characteristics of the prosthesis. Nevertheless, there is no clear scientific evidence concerning the ideal stem length and no consensus regarding the definition of the standard or conventional stems as well as the short stems (SS)[3]. Many authors met the conclusion that SS are those with a length of less than 120 mm[4], while other definitions have also been proposed[3].

The use of SS started more than 30 years ago[5,6]. Clinical studies, meta-analysis as well as comparative studies have shown survival rate similar to conventional stems but for most SS the available data is controversial regarding short or medium term results[7-9]. Several different implants have been currently available[10], classified in different categories[3,11]. Yet, the existing literature regarding clinical results is limited to some of these implants.

Our aim is to report the short-term results of a novel squared section, tapered design –with four conicity- short stem. To the best of our knowledge, this is the first report concerning the clinical use of this particular SS.

MATERIALS AND METHODS

This is a report of a prospectively collected data of 61 consecutive patients undergone THR using the MINIMA® short stem (Lima Corporate, Udine, Italy) (Figure 1) with a minimum follow-up time of 1 year. The study was approved by Ethics committee/Scientific Council of our hospital (SC6/Item 109/28-09-2017).

Operations were performed under either general or spinal anesthesia (chosen by the attending anesthesiologists), using a lateral approach (modified Hardinge). Peri-

Figure 1 The MINIMA® short stem.

operative antibiotic prophylaxis with a second generation cephalosporin (cefoxitin sodium) for 24 h and anticoagulation protocol with low-weight molecular heparin were applied. The appropriate size and orientation of the femoral component were ensured with fluoroscopy after the trial reduction in all cases (Figure 2).

All patients' data including demographics, American Society of Anesthesiology physical status classification system[12], Charlson index[13], diagnosis (arthritis type), hip dysplasia according to Hartophylakidis classification[14] femoral morphology according to Dorr's classification[15], perioperative data including operation time, blood loss, and transfusion rate, length of stay, 90-d re-admissions and complications, were collected prospectively.

The standard postoperative follow-up protocol (at 6 wk, 3 mo, 6 mo, 1 year and every year thereafter) was the same for all patients.

Complications were categorized according to Parvizi *et al*[16] as systemic (major or minor) and local (major or local).

Clinical results were assessed using Harris hip score[17], EuroQol (EQ-5D) 0-100 scale[18], pain score and satisfaction rate using the VAS/NRS scale[19] (Table 1).

Implants

The MINIMA® short stem (Lima Corporate, Udine, Italy) is a cementless, squared section, tapered design stem. It is available in 12 sizes and its length varies between 82 mm and 118 mm. This is a type 3 –standard neck osteotomy, trochanteric spearing-stem[11].

Two different uncemented acetabular components were used (1) a Porous Titanium coating - Titanium plasma spray (SPH-Contact® cup, Lima Corp. Udine, Italy); and (2) a Porous Titanium with HA coating (Delta-PF® cup, Lima Corp. Udine, Italy).

Radiological study

Radiological results were assessed using digital radiographs and a standard system[20]. The modified seven zones of Gruen in anteroposterior and seven zones in lateral radiograph view were evaluated in order to discover any potential (1) radiolucent lines; (2) reactive lines; and (3) cortical hypertrophy[21] (Figure 3).

The femoral stem fixation was classified as stable bone ingrowth, stable fibrous fixation or unstable fibrous fixation[22]. Femoral stem subsidence was measured as the distance between the summit of the lesser trochanter and bottom edge of the stem at 6 wk postoperatively in comparison to the latest follow-up imaging[23].

Leg length discrepancy was measured as the difference between the distances from the inter-teardrop line and the summit of the lesser trochanter of both hips.

Ectopic ossification was probed, according to the classification of Brooker[24].

Proximal femoral stress shielding and bone resorption were investigated, as described by Engh CA[25,26].

Acetabular component evaluation included (1) the presence of radiolucent lines at the bone-prosthesis interface according to DeLee *et al*[27], 1976; and (2) the cup stability according to Manley *et al*[28] criteria.

Manual measurements were performed using IMPAX software (Version 6.3, Agfa IMPAX, AGFA-Gevaert N.V, Mortsel, Belgium). The implanted acetabular shell was used for calibration.

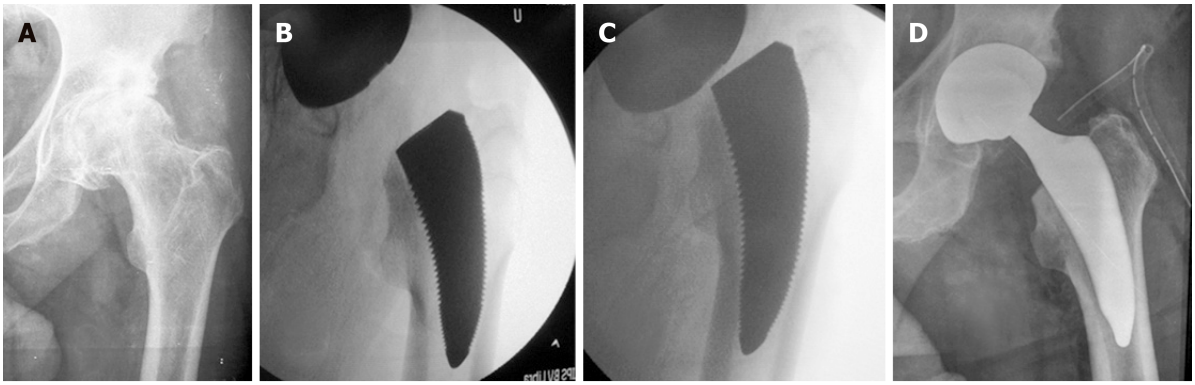

Figure 2 The appropriate size and orientation of the femoral component were ensured with fluoroscopy after the trial reduction in all cases. A: Pre-operative radiograph; B: Intra-operative fluoroscopy after the trial reduction showing a varus and undersizing rasp; C: Correct orientation and sizing; D: Immediate postoperative radiograph.

RESULTS

Sixty one patients were included in this study, with a mean age of 56 years of age (range 25-73 years). Thirty seven of our patients (56.9%) were less than 60 years of age and 42 (68.6%) of the patients were women (Table 1). About half of the patients suffered from primary osteoarthritis (*n*: 33%-54.9%), and the rest of them from secondary osteoarthritis (osteonecrosis, hip dysplasia or other deformities) (Figure 4 and Figure 5), while in 6 patients (9.8%) a previous operation had been performed (femoral osteotomy, vascularized fibular graft, internal fixation for hip fracture) (Figure 5, Figure 6, and Table 2).

The mean time of follow-up was of 33.4 mo (2.8 years) with a range of 12-57 mo (1-4.8 years). In 35 (56.9%) of our patients the follow-up was more than 3 years (Table 1).

Apart from a deep vein thrombosis in one patient at 6 weeks postoperatively, no other complications such us revision, infection, hip dislocation, peri-prosthetic fracture were appeared. Anterior thigh pain was not reported by any of our patients.

Respectively, the mean Pain score, mean HHS, and mean EQ-5D were improved from 6.3, 58.7 and 77.3 preoperatively to 0.1, 95.1, and 79.8 postoperatively (Table 1). The Satisfaction rate at the final follow-up was 9.9 (SD 0.3, range 8.0-10.0).

No patient was re-admitted during the first 90-d nor later for any reason related to the operation.

Radiological findings

Femoral stem: The femoral stem was classified as stable bone ingrowth in all patients[22]. No radiolucent lines were observed in any of the modified seven zones of Gruen in anteroosterior and lateral views[21]. Cortical hypertrophy was observed in 4 patients (6.6%) (Figure 7). In 2 patients reactive lines were observed in zones 3, 4 and 5 (Figure 8). The calculated mean stem subsidence was 1.8 mm (SD 0.9, range 0.0-3.9 mm).

Proximal femoral stress shielding and bone resorption were graded radiologically as grade 1 in all patients[25].

The mean leg length discrepancy was 1.7 mm (SD 5.4) with a wide range (from -17 to 19 mm) due to the relatively high prevalence of patients with a secondary osteoarthritis (45.1%), -dysplastic hips, bilateral in most cases.

Acetabular component: No radiolucent lines were observed in any zones according to DeLee *et al*[27] (1976). All cups were classified as stable according to Manley *et al*[28] (1998) criteria.

DISCUSSION

According to the findings of the present study the clinical and radiological results were excellent in the short-term follow-up using the MINIMA® short stem in THR. Despite the short follow-up time and the small number of cases, no revision for any cause was performed, no radiological signs for loosening or impending loosening were observed, no periprosthetic fractures were presented and clinical scores and patients' satisfaction were excellent.

Comparing our results to those of the existing literature, it is difficult to draw safe

Table 1 Demographics and clinical data

Characters	Values
Number of patients[1]	61
Gender female[2]	42 (68.6%)
Gender male[2]	19 (31.4%)
Age (yr)[3]	56 ± 11.1 (25-73)
BMI[3]	31.2 ± 4.9 (22.8-50.0)
ASA[3]	1.8 ± 0.6 (1.0-3.0)
Charlson index[3]	1.2 ± 0.5 (0.0-3.0)
LOS (d)[3]	3.3 ± 1.1 (2.0-8.0)
Operating time (min)[3]	89.9 ± 17.2 (60.0-120.0)
Blood loss (mL)[3]	1.154 ± 0.213 (0.735-1.631)
Transfusion rate[2]	2 (3.9%)
Follow-up (mo)[3]	33.4 ± 15.8 (12-57)
Follow-up (yr)[3]	2.8 ± 1.3 (1-4.8)
Follow-up more than 3 yr[2]	35 (56.9%)
Painpre-operative[3]	6.3 ± 1.9 (2.8-8.0)
Pain final follow-up[3]	0.1 ± 0.4 (0.0-2.0)
HHS pre- operative[3]	58.7 ± 13.5 (33.0-78.0)
HHS final follow-up[3]	95.1 ± 4.9 (83.0-100.0)
EQ-5D pre- operative[3]	77.3 ± 16.7 (50.0-95.0)
EQ-5D final follow-up[3]	79.6 ± 12.1 (50.0-100.0)
Satisfaction final follow-up[3]	9.9 ± 0.3 (8.0-10.0)
Complications	
Deep vein thrombosis[2]	1

[1]The values are given as raw numbers.
[2]The values are given as raw numbers with the percentages in parentheses.
[3]The values are given as the mean ± SD and the range in parentheses. BMI: Bone mass index; ASA: American Society of Anesthesiologists score; LOS: Length of stay, HHS: Harris hip score; EQ-5D: EuroQol.

conclusion, because there are no other report concerning the use of this particular stem in THR. A recent review of the literature has shown that the calculated overall median revision rate is comparable to those of conventional stems of National Registries, but the survival rate of SS depends on the type of the stem[9]. The best results have been reported for type 2 stems followed by the type 3 stems, while the revision rate for type 1 has been disappointing. The MINIMA® short stem belongs to the type 3 category – a standard femoral neck osteotomy stem.

Furthermore, the available comparative studies and a subsequent meta-analysis have shown no significant differences between SS and conventional stems in the short-term follow-up[8].

However, the available clinical results (either observational or comparative studies) are limited to some of the several different implants that have been currently used.

Despite their theoretical advantages and the reported encouraging results the use of SS has not gained yet a wide acceptance among the orthopaedic surgeons.

Short stem advantages

The advantages of using short stems in THR's include (1) the removal of less bone in the proximal femur; (2) a subsequent "easier" stem revision as less bone is expected to be "violated"; (3) less bone remodeling or bone mineral changes of the proximal femur (proximal stress-shielding); and (4) less anterior thigh pain. Finally, another important benefit of short stems is that enables surgeons to overcome the problem of the proximal-distal mismatch due to Dorr type A femur, femoral shape or femoral deformity.

In our series, no cases with stem revision were required, therefore we cannot confirm the "easiness" of revision. The future will show the benefit for our patients since 37 (56.9%) of these patients were less than 60 years of age and some or most of them are going to undergo a revision surgery in the future.

No cases with postoperative thigh pain were observed. The MINIMA® short stem was used in 11 (17.6%) patients with Dorr type A femur.

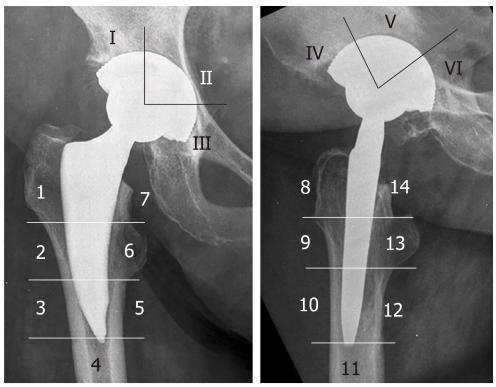

Figure 3 The modified Gruen zones.

Proximal bone remodeling or bone mineral changes were not estimated in our study. Bone remodeling seems to be less for short stems according to a recent literature review, although the results are not the same for all SS designs[29]. Furthermore, according to a recent report based on data from the existing literature, the bone mineral changes around femoral stems (cemented, cementless, conventional and short stems) are not predictive for the level the satisfaction of long term clinical outcomes regarding total hip arthroplasty[30]. Therefore, the authors suggested that studies with a follow up shorter than 5-10 years are perhaps clinically irrelevant[30].

Short stem disadvantages

The three main concerns for short stems are (1) the possible stem malposition (and stem undersizing) due to lack of distal extension to guide position within the canal and subsequent stem subsidence; (2) possible inadequate early stability, stem micromotion and subsequent fibrous ingrowth instead of bone ingrowth; and (3) the long-term clinical results.

We believe that the routine use of intra-operative fluoroscopy guaranteed proper implant orientation and correct sizing in our series. This fact eliminated the influence of the surgical technique as a confounding factor in stems' survivorship.

As far as the early stem stability is a concern, our clinical impression is that it is provided by the design of this particular stem. Specifically, it is (1) the taper design - with four taper conicity- to avoid sinking; and (2) the squared section providing torsional stability.

The long-term results concerning the use of MINIMA® short stem cannot be predicted from the results of this study.

Stem subsidence (distal migration)

Roentgen stereophotogrammetric analysis is generally accepted as the most accurate method of femoral stem subsidence (distal migration),as well as Einzel-Bild-Roentgen-Analyse femoral component analysis, which also allows accurate measurement of femoral stem subsidence[31-33]. The IMPAX software, which was used in the present study, has been used before[34], although we are not aware of its accuracy in measuring the stems' distal migration.

Stem subsidence was within acceptable limits in our series. It was calculated more than 3 mm only in 3 patients, but no other radiological signs or symptoms of stem loosening were recorded.

Femoral stem subsidence is usually measured using as reference points the tip of the greater trochanter and the proximal end of the femoral stem[35].

We noticed, that radiographic changes of the tip of the greater trochanter –heterotopic ossification- in 11 (17.6%) of our patients were presented. This fact made the measurement less reliable in some cases in our study. Therefore, we used as reference points the summit of the lesser trochanter and the bottom edge of the stem for measurement of the femoral stem subsidence[23].

Distal cortical hypertrophy

The incidence of distal cortical hypertrophy varies among different studies. Despite the different hypotheses for its development and the excellent short-term clinical results, the exact cause or pathogenesis and the long-term clinical results in patients with this radiological finding remains unknown[36].

The incidence in our study was relatively low, since in 4 (6.6%) of our patients a cortical hypertrophy was observed in Gruen's modified ones 3 and 5. Nevertheless, a

Table 2 Arthritis type bone morphology and radiological findings

	n (%)
Arthritistype	
Primaryosteoarthritis	33 (54.9)
Dysplasia (type A)[1]	13 (21.6)
Low dislocation (type B)[1]	2 (3.9)
Osteonecrosis	7 (11.8)
Post traumaticarthrtis	4 (5.9)
Other	1 (2.0)
Previous operation (osteotomy, Fracture fixation)	6 (9.8)
Proximal femoral morphology (Dorr type)	
A	11 (17.6)
B	48 (78.4)
C	2 (3.9)
Ectopic ossification (Brooker classification)	
All	11 (17.6)
Class 1	6 (9.8)
Class 2	5 (7.8)
Modified Gruen zones	
Radiolucent lines	0
Reactive lines (zones 3, 4, 5)	2 (3.3)
Cortical hypertrophy (zones 3, 5)	4 (6.6)
Subsidencein mm[2]	1.8 ± 0.9 (0.0-3.9)
Leg length discrepancy in mm[2]	1.7 ± 5.4 (-17-19)

[1]Chartofylakidis classification.
[2]The values are given as the mean ± SD and the range in parentheses.

careful follow-up of these patients is required.

The main limitation of this study is the fact that it is a clinical and radiological report with a small number of cases and short-term follow-up. Future studies with large number of patients and longer follow-up time are required in order to ensure the safety and efficacy of using this particular short stem in THR patients.

Nevertheless the clinical and radiological results are excellent, without major complications and the follow-up in 56.9% of our patients is more than 3 years.

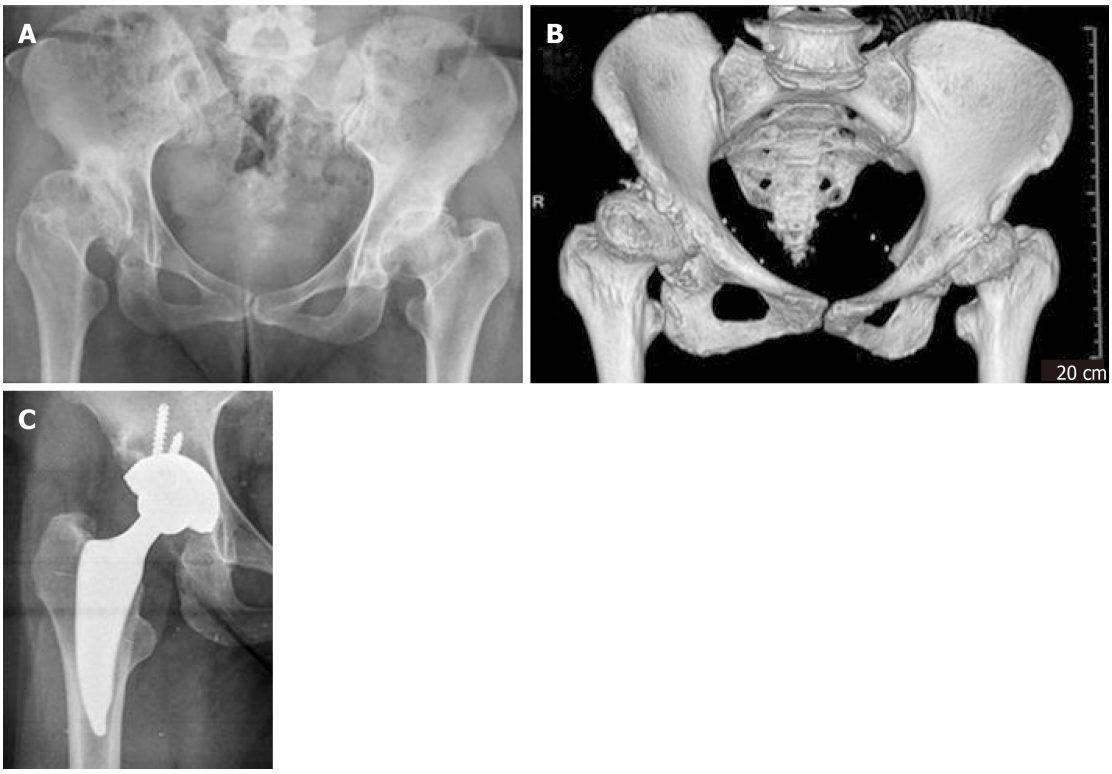

Figure 4 Hip dysplasia Hartophylakidis type II at the right side, and radiographs at 3 years postoperatively. A, B: Hip dysplasia Hartophylakidis type II at the right side; C: Radiographs at 3 years postoperatively.

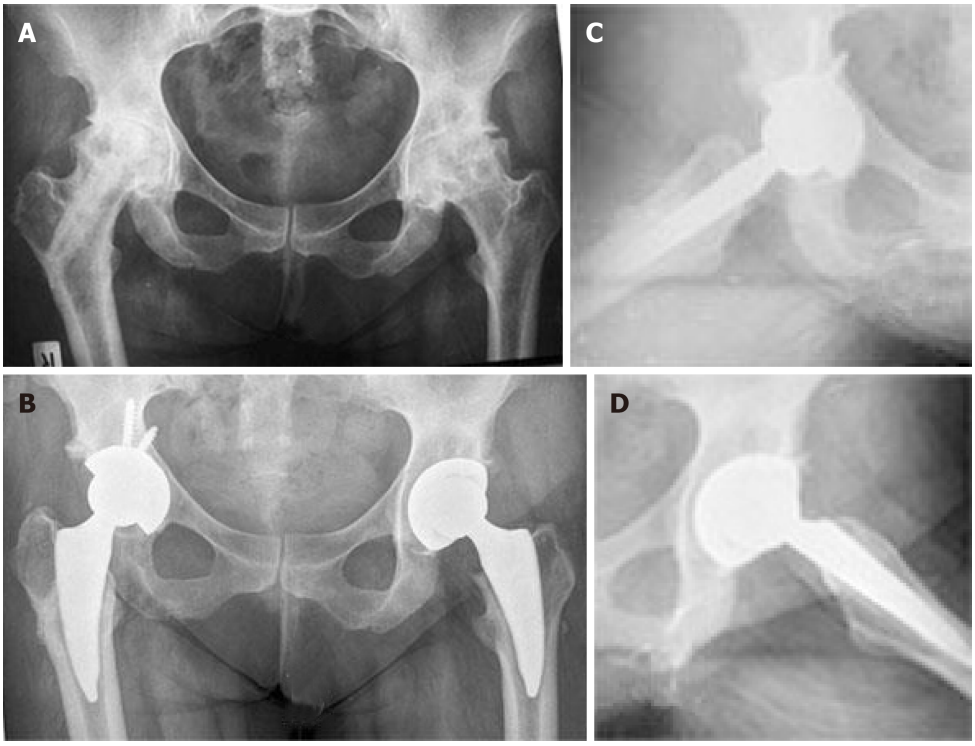

Figure 5 Bilateral osteonecrosis in a 24 years female patient suffered from lymphoma. A: Patient treated on the right side with a vascularized fibular graft; B: Postoperative radiographs 4 years postoperatively on the right side; C: 3 years on the left side; D: Lateral radiographs.

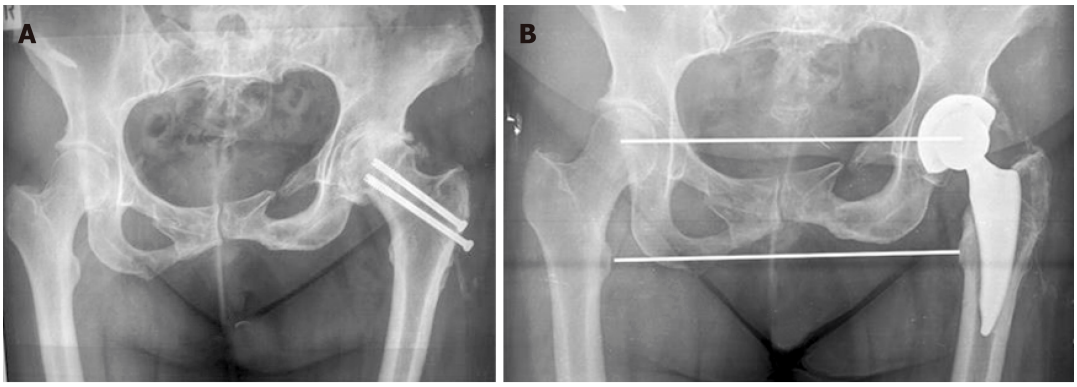

Figure 6 Ectopic ossification. A: Posttraumatic osteoarthritis; B: Radiographs at 4 years postoperatively.

Figure 7 Distal cortical hypertrophy at modified Gruen zones 3 and 5.

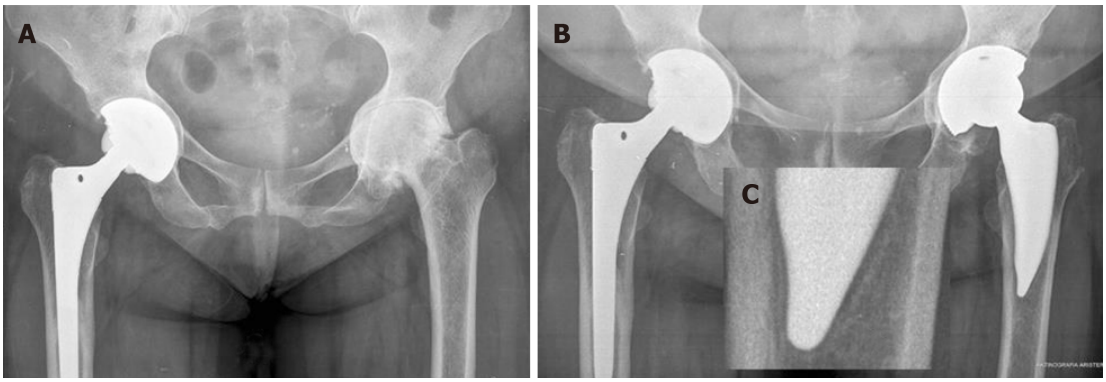

Figure 8 Reactive lines were observed in zones 3, 4 and 5. A: Preoperative radiographs showing "protrusion acetabuli" and Dorr type C proximal femur; B: Postoperative radiographs at two years; C: Reactive lines in zones 3, 4 and 5.

ARTICLE HIGHLIGHTS

Research background

Total hip replacement is considered as one of the most successful procedures in orthopedic surgery. The length of the femoral stem is one of the most important geometrical and mechanical characteristics of the prosthesis. The use of short stems started more than 30 years ago.

Research motivation

Clinical studies, meta-analysis as well as comparative studies have shown similar survival rate between conventional and short stems. However, for most short stems the available data is controversial regarding short or medium term results. Several different implants have been currently available, classified in different categories. Yet, the existing literature regarding clinical results is limited to some of these implants.

Research objectives
Our aim is to report the short-term clinical and radiological results of a novel squared section, tapered design –with four conicity- short stem in total hip replacement.

Research methods
This is a report of a prospectively collected data of 61 consecutive patients undergone total hip replacement using the MINIMA® short stem (Lima Corporate, Udine, Italy) with a minimum follow-up time of 1 year.

Research results
The mean time of follow-up was of 33.4 mo (2.8 years) with a range of 12-57 months (1-4.8 years). Apart from a deep vein thrombosis in one patient at 6 weeks postoperatively, no other complications such us revision, infection, hip dislocation, peri-prosthetic fracture were appeared. Additionally, the functional outcomes, pain score and satisfaction rate were significantly improved at the postoperative follow- up period. The femoral stem was classified as stable bone ingrowth in all patients. No radiolucent lines were observed in any of the modified seven zones of Gruen in anteroposterior and lateral views. Regarding the femoral component, no radiolucent lines were observed in any zones according to DeLee and Charnley.

Research conclusions
The clinical and radiological results of our study are considered as excellent, without major complications and the follow-up in 56.9% of our patients is more than 3 years.

Research perspectives
Further research based on well designed studies with longer follow-up examination need to be performed, in order to elucidate the efficacy of short stems.

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World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2020 April 18; 11(4): 243-251

DOI: 10.5312/wjo.v11.i4.243

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Prospective Study

Kitesurf injury trauma evaluation study: A prospective cohort study evaluating kitesurf injuries

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Author contributions: van Bergen CJA, Weber RIK and Kraal T are kitesurfers, analyzed the data and wrote the paper; Weber RIK, Kraal T and Haverkamp D designed and performed the study; Kerkhoffs GMMJ and Haverkamp D commented on the drafts.

Institutional review board statement: The study was reviewed and approved by the Slotervaartziekenhuis and Reade Institutional Review Board.

Clinical trial registration statement: This study was not registered in a clinical trial registration.

Informed consent statement: All involved persons gave their informed consent prior to study inclusion.

Conflict-of-interest statement: The authors have no conflict of interest to report.

Data sharing statement: There is no additional data available.

CONSORT 2010 statement: The authors have read the CONSORT 2010 Statement. The manuscript was prepared and revised according to the CONSORT 2010 Statement as far as possible because the study is not a randomized controlled trial.

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Abstract

BACKGROUND

Kitesurfing is an increasingly popular and potentially dangerous extreme water sport. We hypothesized that kitesurfing has a higher injury rate than other (contact) sports and that the minority of injuries are severe.

AIM

To investigate the incidence and epidemiology of kitesurfing injuries in a Dutch cohort during a complete kitesurfing season.

METHODS

Injury data of 194 kitesurfers of various skill levels, riding styles and age were surveyed prospectively during a full kitesurf season. The participants were recruited through the Dutch national kitesurf association, social media, local websites and kitesurf schools. Participants completed digital questionnaires monthly. The amount of time kitesurfing was registered along with all sustained injuries. If an injury was reported, an additional questionnaire explored the type of injury, injury location, severity and the circumstances under which the injury occurred.

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Manuscript source: Invited manuscript

Received: December 18, 2019
Peer-review started: December 18, 2019
First decision: January 6, 2020
Revised: March 14, 2020
Accepted: March 26, 2020
Article in press: March 26, 2020
Published online: April 18, 2020

P-Reviewer: Malik H, Mesquita J
S-Editor: Dou Y
L-Editor: A
E-Editor: Xing YX

RESULTS

The mean age of participants was 31 years (range, 13-59) and the majority of the study population was male (74.2%). A total of 177 injuries were sustained during 16816 kitesurf hours. The calculated injury rate was 10.5 injuries per 1000 h of kitesurfing. The most common injuries were cuts and abrasions (25.4%), followed by contusions (19.8%), joint sprains (17.5%) and muscle sprains (10.2%). The foot and ankle were the most common site of injury (31.8%), followed by the knee (14.1%) and hand and wrist (10.2%). Most injuries were reported to occur during a trick or jump. Although the majority of injuries were mild, severe injuries like an anterior cruciate ligament tear, a lumbar spine fracture, a bimalleolar ankle fracture and an eardrum rupture were reported.

CONCLUSION

The injury rate of kitesurfing is in the range of other popular (contact) sports. Most injuries are relatively mild, although kitesurfing has the potential to cause serious injuries.

Key words: Kite boarding; Water sports; Sports medicine; Injuries; Epidemiology; Extreme sports

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Core tip: Kitesurfing is an increasingly popular extreme water sports with the potential to cause serious injuries. This paper presents a unique prospective cohort study investigating injuries during a complete kitesurf season. An injury rate of 10.5 per 1000 h of kitesurfing was found. Most of the injuries associated with kitesurfing are relatively mild, although kitesurfing causes severe injuries as well. Furthermore, it was shown that the foot and ankle are the most injured body parts. The outcomes of this study may provide clues for prevention.

Citation: van Bergen CJA, Weber RIK, Kraal T, Kerkhoffs GMMJ, Haverkamp D. Kitesurf injury trauma evaluation study: A prospective cohort study evaluating kitesurf injuries. *World J Orthop* 2020; 11(4): 243-251
URL: https://www.wjgnet.com/2218-5836/full/v11/i4/243.htm
DOI: https://dx.doi.org/10.5312/wjo.v11.i4.243

INTRODUCTION

Since its introduction in the mid-1990s, kitesurfing has become an increasingly popular sport. It is probably the fastest growing water sports and has become an Olympic sport recently[1]. Although retrospective studies report injury risks within the range of other sports[1,2], kitesurfing is considered an extreme sport[3-5] and kitesurfers are often seen as thrill seekers. Prospective high quality studies concerning the injury risk of kitesurfing are scarce[5]. Therefore, the image of the sport is most likely based on media headlines.

Kitesurfing is a water sport that combines elements of several different sports like power kiting, wakeboarding, surfing and windsurfing. A kite, ranging in size from approximately 5 to 20 m^2, is used to convert wind energy into forward motion. The kitesurfer is attached to this kite by four or five lines, a handlebar and harness (Figure 1). The athlete stands on a board; this board varies in size and shape, dependent on the style of kitesurfing preferred by the athlete. Kitesurfing can roughly be divided in three different disciplines. Freestyle mostly revolves around performing jumps and tricks (Figure 2); athletes generally use rectangular symmetrically shaped boards (twintips). The course race discipline is more similar to sailing; these kitesurfers use larger non-symmetrical boards (raceboards) with the aim to reach a finish line as fast as possible. The wave discipline is aimed at surfing waves; these boards closely resemble regular surfboards (directionals). One could imagine that the injury risks differ per discipline. In general, most recreational kitesurfers will incorporate different aspects of these disciplines in their kitesurf sessions. As with every relatively new sport, kitesurfing is subject to significant change and evolution, leading to a range of different safety systems and protective gear. Safety systems to depower the kite and a

quick-release system to detach the kite from the harness have become standard in recent years and are now widely used. Other changes in kite design, lines and control bars have made kites considerably easier to control, making the sport more accessible and easier to learn.

There is no recent prospective study evaluating the injury risk and epidemiology of kitesurfing injuries after these innovations. The only prospective cohort study amongst kitesurfers was done in 2002. In this study, the authors concluded that kitesurfing is an extreme sport with the potential to cause serious harm to its participants. There has not been another prospective study evaluating injury risk in kitesurfing. Thus, the safety of the sport can only be judged on outdated literature. Meanwhile, kitesurf equipment and protective gear has developed significantly. Therefore, the purpose of this study was to determine the current injury rate, the severity of the injuries and possible factors influencing the safety aspects of kitesurfing.

MATERIALS AND METHODS

This is a prospective cohort study during a single kitesurf season from April to November. The local medical ethics committee approved the study protocol. Kitesurfers were recruited through the Dutch national kitesurf association, local kitesurf websites (www.hanglos.nl, www.kitehigh.nl), social media (Facebook) and Dutch kitesurfschools. Dutch speaking riders of all skill levels, riding styles and age were included for participation. Informed consent was obtained from all kitesurfers prior to study participation. Participants were able to register on a website with an online database system with anonymous registration of the data but allowing the researcher to follow up on missing data. The data was collected monthly and a reminder was sent to all participants failing to enter their monthly update.

At baseline registration, all participants completed a web-based questionnaire with data including age, sex, years of experience, type of equipment used, hours of kitesurf lessons received, competitive riding level, safety system usage and hours spent practicing different sports per week. All participants were asked to monitor the amount of hours spent kitesurfing per month. Participants were instructed to report every type of physical injury, including cuts and abrasions, due to kitesurfing sustained in the concerned month. If an injury was reported, an additional questionnaire explored the type and severity of the injury and the circumstances under which the injury occurred. If a participant sustained more than one injury during a month, he or she was instructed to fill out a separate questionnaire for each injury.

The injury-specific questionnaire was divided in three distinct parts. The first part evaluated the circumstances and possible causes which led to the sustained injury: The style of riding at the time of the injury, the time of the injury (beginning, middle, or end of the session), water conditions (flat water, choppy, waves), wind speed and direction. Further questions evaluated potential causes of the injury: attempted trick or maneuvers, kite control, equipment failure, lack of experience, collision with other persons. The second part of the questionnaire evaluated the specifics of the injury itself: The anatomical location of the injury, the type and severity of injury, consultation of medical care, received diagnostics and treatment, the diagnosis, days admitted in hospital and the period the athlete was unable to kitesurf due to the injury. The final part of the questionnaire evaluated the gear used at the time of the injury: Production year of the kite, type of board, type of bindings (footpads and straps, boots or strapless), protective gear used, and whether a quick-release system was used.

At the end of the kitesurfing season all athletes who still had missing data were contacted by e-mail with a request to report the missing data retrospectively. Kitesurfers who never responded in any month (due to incorrect e-mails or other reasons) were considered non-responders. In addition to the data provided by the participating athletes, local and national media were monitored for fatal accidents amongst the participants of the study.

Statistical analysis

Descriptive statistics were used for the demographic characteristics of participants. Injury location was classified in nominal categories with respect to the different body areas. A descriptive analysis for injury severity was used referring to the consequences of the injury. The injury rate per 1000 h of kitesurfing was calculated. Injury rates were compared between different levels of experience using the χ^2 test. A *P*value of 0.05 was considered statistically significant.

Figure 1 A fully equipped kitesurfer. 1: Kite; 2: Handlebar; 3: Quick-release system; 4: Harness.

RESULTS

Baseline characteristics

A total of 253 kitesurfers registered for participation on the website. Eight participants ended their cooperation due to personal reasons. Another 51 participants were non-responders. This left 194 kitesurfers eligible for data collection during the season. The average monthly response rate of these 194 included kitesurfers was 89.2%. The mean age of participants was 31 years (range, 13-59) and the majority of the study population was male (74.2%). The largest portion of participants (43.8%) had 3-5 years of experience. Three to ten hours of kitesurfing lessons was reported by 42.8% of the participants and only 14.9% received no lessons at all. The vast majority (91.8%) of the participating kitesurfers used a twintip kiteboard with straps (Table 1).

Injury rate

The 194 participants recorded a total of 16816 h of kitesurfing during the study period. A total of 177 injuries were reported. This leads to a calculated injury rate of 10.5 injuries per 1000 h of kitesurfing.

Injury type and location

The most common injuries were cuts and abrasions (25.4%), followed by contusions (19.8%), joint sprains (17.5%) and muscle sprains (10.2%). There were only 7 (4.0%) fractures reported (Table 2), including foot, spine, ankle and wrist fractures. All were treated nonoperatively. The foot and ankle were the most common sites of injury (31.8%), followed by the knee (14.1%) and hand and wrist (10.2%) (Table 3). Injuries of the foot and ankle included a bimalleolar ankle fracture, three phalangeal fractures and three ankle sprains. Injuries of the knee included 13 knee sprains, two meniscal tears and two anterior cruciate ligament tears. Hand and wrist injuries included five abrasions, three wrist sprains, and one metacarpal fracture. Other fractures included a cervical spine fracture and a lumbar spine fracture.

Injury severity and consequences

A medical doctor was consulted in 14.1% of the injuries. This concerned a medical specialist in 7.3%, a general practitioner in 5.1% and an emergency physician in 1.7% of the cases. Only 2.9% of the injuries led to an admission in the hospital. In 83.1% of the injuries the athlete was able to return to kitesurfing within one week. In 3.9% of the injuries the kitesurfer reported to be unable to kite for two months up to a complete season. There were no kitesurf injuries that prevented a kitesurfer from ever practicing the sport again. There were no fatal injuries in our study cohort.

Injury cause and environmental factors

The majority of the injuries were sustained in wind speeds of 4-6 Beaufort and flat to small wave (choppy) conditions, which are typical Dutch conditions. The vast majority (91.0%) of the injuries were sustained on the water. However, 49.2% of the injuries were sustained in shallow water and nine percent of the injuries were caused by an accident on the shore. Interestingly, all fractures were either sustained in shallow water or on the shore. Half of all of injuries were sustained attempting a jump or trick (Table 4). In 15.8% of the injuries the athlete reported that lack of experience played a role in sustaining the injury. Loss of kite control was reported in 10.7% as a cause of the injury, and gear failure in 3.4%. In only 2.8%, the injury was caused by contact or collision with someone else on the water.

Figure 2 A kitesurfer on a twintip board performing a freestyle jump.

Most injuries were found amongst kitesurfers with 3-5 years of experience, but this was also the largest group of participants that reported the most hours of kitesurfing in the study period. A trend was observed for a decreasing injury rate with an increasing level of experience. Beginners with less than one year of experience had an injury rate of 17.5. With 3-5 years of experience the injury rate was 11.5 and this decreased to 7.8 injuries per 1000 h in participants with more than 10 years of experience. However, this did not reach statistical significance (OR = 2.23; 95%CI: 0.99-4.98; P = 0.052).

Injury prevention

In 97.9% of the injuries the athlete was in possession of a quick-release system to detach the kite from their harness. However, in only 7.3% of the injuries the quick-release was actually used. An impact-vest was used by 19.5% of participants on a regular basis, and 4.0% used a helmet on a regular basis. Other protective gear such as a knee brace or spine protector was used by 12.3% of the kitesurfers.

DISCUSSION

This prospective cohort study collected data regarding kitesurfing injuries among a representative group of Dutch kitesurfers during one full season in the Netherlands. The majority of the injuries were mild, demonstrated by our results that more than 80% of the athletes were able to return to kitesurfing within one week and medical help was sought in only 14% of the injuries.

An injury rate of 10.5/1000 h was found in this study. A wide range in injury rate is described for kitesurfing in the existing literature from 1.04/1000 h[6] up to 18.5/1000 h[2] in competitive kitesurfers. Nickel *et al*[4] conducted the only comparable prospective study on kitesurfing injuries in 2002, reporting an injury rate of 7/1000 h. These injury rates of kitesurfing are not disproportionally high compared to other sports, such as motocross (22.7/1000 h)[7], soccer (18.5/1000 h)[8], and American football (36/1000 h)[9] (Figure 3). van Bergen *et al*[10] reported a higher injury rate amongst kitesurfers (7.0/1000 h) in comparison with windsurfers (5.2/1000 h).

It is important to note that the injury rate is an outcome parameter that can be influenced greatly by several factors, concerning both the numerator and the denominator. At first, there is no strict definition of an injury. It can be questioned if an abrasion or a skin cut from shells really is a "countable" injury if it does not lead to inability to practice the sport. Furthermore, for a sport like kitesurfing, it is difficult to report the exact amount of time that the sport is practiced, given the recreational nature of the sport without scheduled training moments. In our study, the participants reported the amount of hours spent kitesurfing at the end of each month.

In accordance to our findings, similar types of injuries were described by Nickel *et al*[4], with contusions, lacerations and joint sprains being the most common injuries. Also consistent with our findings, the foot and ankle were the most common locations of injury. We hypothesize that the contact forces during landing and fixation of the forefoot in straps during rotational maneuvers are related to the common foot and ankle injuries.

A contrasting finding is that the use of a quick-release system was available in only 18% of the athletes in 2002[4], which increased to 97.9% in our study. A quick-release system is typically used when there is loss of kite control. It is generally accepted that the current quick-release systems are easier to use and more reliable than > 10 years

Table 1 Baseline characteristics

Characteristic	*n*	%
Sex		
Male	144	74
Female	50	26
Age (yr)		
10-20	21	11
20-30	79	41
30-40	63	32
40-50	24	12
50-60	8	4.1
Experience (yr)		
< 1	13	6.7
1-2	27	14
3-5	85	44
5-10	51	26
> 10	18	9.2
Lessons		
0	29	15
1-3	44	23
3-10	84	43
> 10	37	19
Board type		
Twintip	178	92
Directional	11	5.6
Race	1	0.5
Different	4	2.1
Protection		
Quick-release	190	98
Impact vest	38	20
Helmet	8	4.1
Different	24	12

ago. Nickel *et al*[4] already described a trend toward a decreasing injury rate with the use of a quick-release system. Interestingly, we noted that the quick-release system was used in only 7.3% of the injuries. This is most likely related to the finding that loss of kite control was only reported in 10.7% of the injuries. Another possible explanation might be a high threshold to actually use the quick-release system.

Although kitesurfing equipment has become safer in recent years, our study did not demonstrate a lower injury rate compared to previous studies. Similarly, Baumbach *et al*[2] in 2018 reported a high injury rate of 18.5/1000 h despite a statistically significant influence of the equipment used. Several explanations can be hypothesized for this discrepancy. With the increased popularity of kitesurfing and the improved equipment, the sport has become more accessible to people who are less physically fit and not familiar with watersports or flying a kite, compared to the early years of kitesurfing. The increased popularity can also lead to crowding of kitesurf spots, causing accidents. However, in our study, injuries caused by collisions with others was reported in only 2.8%. Another factor is that even minor injuries like cuts and abrasions were included in this study.

Although the majority of the injuries reported in our study were mild, there is no doubt about the potential for severe injuries due to kitesurfing. A combination of an anterior cruciate ligament with medial collateral ligament injury was reported after a valgus rotational trauma during a landing of a powered trick (a railey). A lumbar spine fracture was reported, sustained on the beach after loss of kite control during landing the kite. An eardrum tear was reported due to a crash with the ear on the water while attempting a kiteloop. Further examples of serious injuries in our study were a cervical spine fracture and a bimalleolar ankle fracture. The potential for serious risks in kitesurfing are also displayed in the case series of Spanjersberg *et al*[5]

Table 2 The types of injuries

Injury	*n*	%
Abrasion	45	25
Contusion	35	19
Joint sprain	31	19
Muscular sprain	18	10
Deep/open wound	16	9.0
Fracture	7	4.0
Concussion	7	4.0
Ligament rupture	4	2.2
Meniscus tear	2	1.1
Nerve damage	1	0.6
Other	11	6.2
Total	177	100

and Driessen *et al*[3] in which they report severe multitrauma patients with various injuries leading to persisting handicap and even death in several cases.

The relatively large amount of non-responders is a limitation of this study. This was probably due to the fact that only after online registration participants realized the quantity of data that we requested for participation. Medical diagnoses of the reported injuries were not confirmed with physical examination or diagnostic imaging by the authors of the study. This study relied on the description of the injury from the injured participant. Furthermore, a clear definition of an injury with respect to the severity was not found in the literature. In this study, we chose to use an injury definition that took every form of physical harm into account, as advised in multiple consensus statements by experts in sports medicine[11-14]. With this approach, the risk of underestimating the occurrence of injuries is minimized. The downside is that some of the smaller injuries that participants registered, such as blisters, might be considered as normal "side effects" of the sport instead of real injuries. There were a relative low number of participants in the disciplines wave and race compared to freestyle. This made it impossible to distinguish the risks between the different kitesurfing disciplines.

In conclusion, an injury rate of 10.5/1000 h kitesurfing was found in this prospective cohort study. The injury rate is not disproportionally high compared with other contact sports. A decreased injury rate compared to previous literature with the evolution of the sport was not demonstrated. Most of the injuries were relatively mild. However, this study also confirms that kitesurfing has the potential to cause severe injuries.

Table 3 Affected anatomical locations

Location	*n*	%
Foot	45	25
Knee	25	14
Hand/wrist	18	10
Head	14	7.9
Calf	14	7.9
Ankle	11	6.2
Shoulder	8	4.5
Chest	7	4.0
Fingers	7	4.0
Upper arm	4	2.3
Elbow	4	2.3
Hip	4	2.3
Back	4	2.3
Neck	3	1.7
Upper leg	2	1.1
Forearm	1	0.6
Other	6	3.4
Total	177	100

Table 4 Maneuver at the time of the injury

Maneuver	*n*	%
Jump or trick	87	49
Cruising	46	26
Walking with kite	16	9.0
Wave riding	10	5.6
Landing kite	3	1.7
Launching kite	2	1.1
Other	13	7.3
Total	177	100

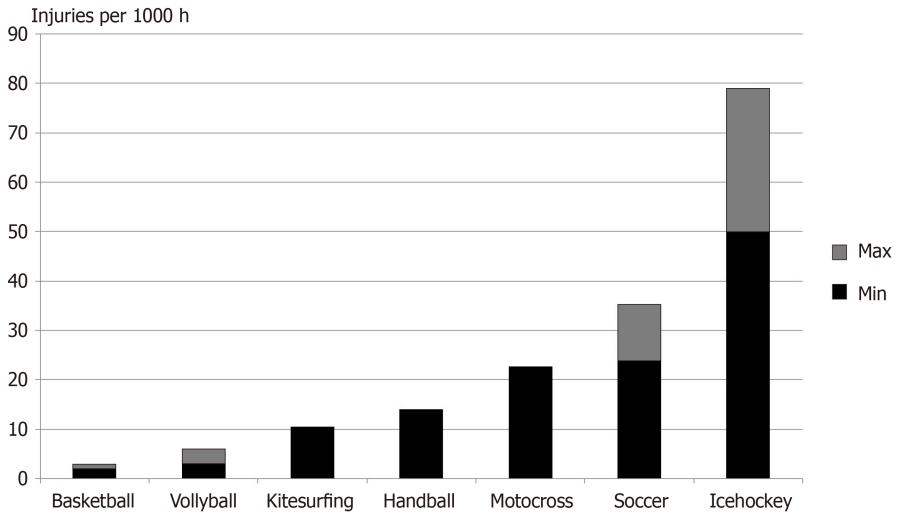

Figure 3 Injury rates in different sports compared with kitesurfing[6,7,11,12].

ARTICLE HIGHLIGHTS

Research background
Kitesurfing is a rapidly growing extreme water sport with a high injury potential.

Research motivation
The only prospective study on kitesurf injuries is from 2004. Kitesurf equipment has developed over the past years.

Research objectives
The purpose of the study was to identify injury patterns and incidence rates of kitesurfers with modern equipment.

Research methods
A prospective study was performed investigating a large number of kitesurfers during a full kitesurf season.

Research results
The injuries were similar to previous research, despite the use of modern equipment. Furthermore, the injury rate was within the range of other extreme sports.

Research conclusions
Kitesurfing is a relatively safe water sport, although severe injuries do occur.

Research perspectives
To further decrease the risk of injuries, future studies can be directed towards the use of protective gear as well as other protective measures such as designated areas.

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