Rotator cuff repair in patients over 70 years of age

EARLY OUTCOMES AND RISK FACTORS ASSOCIATED WITH RE-TEAR

This study reports the clinical and sonographic outcome of arthroscopic rotator cuff repair in patients aged ≥ 70 years and aimed to determine factors associated with re-tear. A total of 69 consecutive repairs were performed in 68 patients with a mean age of 77 years (70 to 86). Constant-Murley scores were collected pre-operatively and at one year post-operatively. The integrity of the repair was assessed using ultrasound. Re-tear was detected in 20 of 62 patients (32%) assessed with ultrasound. Age at operation was significantly associated with re-tear free survival (p = 0.016). The mean pre-operative Constant score was 23 (SD 14), which increased to 58 (SD 20) at one year post-operatively (paired t-test, p < 0.001). Male gender was significantly associated with a higher score at one year (p = 0.019).

We conclude that arthroscopic rotator cuff repair in patients aged ≥ 70 years is a successful procedure. The gender and age of the patient are important factors to consider when planning management.

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The incidence of rotator cuff tears (RCTs) increases with age. Cadaveric studies have demonstrated full thickness tears in 30% of subjects aged > 60 years1 and MRI studies have shown full-thickness tears in 28% of those aged > 60 years.2 In patients aged > 70 years, the prevalence of asymptomatic full thickness RCTs is about 38% as diagnosed by ultrasound scan.3

The United Nations uses the age of 60 years to describe ‘older’ people. In developed countries elderly may be considered to be older than this, with the retirement age moving towards 68 years. In this study we have taken elderly to mean age ≥ 70 years. However, we acknowledge that chronological ageing is not a precise marker of biological ageing.

Arthroscopic rotator cuff repair (ARCR) is increasingly used because it is minimally invasive and causes less soft-tissue damage, potentially allowing a faster recovery than open repair. Rotator cuff repair in elderly patients is, however, controversial for several reasons. They are more likely to have osteoporosis of the proximal humerus and poorer tendon quality4 and those aged > 65 years have a higher proportion of technically challenging, massive (≥ 5 cm) RCTs,5 which are associated with greater tendon degeneration, reduced cellular activity and poorer potential for healing.5–8 Increasing age is also associated with a high rate of re-rupture following repair.9,10

This prospective study aimed to report the clinical and sonographic outcome of patients aged ≥ 70 years who underwent arthroscopic repair of a full-thickness RCT and to determine the factors associated with clinical outcome and re-tear.

Patients and Methods

Between September 2006 and December 2009, a total of 69 ARCRs were performed in 68 consecutive patients with a symptomatic full-thickness RCT. Their mean age was 77 years (70 to 86). There were 33 males and 35 females (one female with bilateral tears repaired at different times).

The median duration of symptoms was 14 months (1 to 100). Of the 67 RCTs for which these data were collected, 29 (43%) were associated with a history of injury involving the shoulder. The American Society of Anesthesiologists (ASA) grade11 was recorded for 61 patients: it was grade 1 in seven (11%), 2 in 48 (79%), 3 in five (8%) and 4 in one (2%).

Consecutive patients aged ≥ 70 years who underwent ARCR were included in the study. Before consideration for surgery, all patients received shoulder physiotherapy in primary or secondary care settings. Patients who had failed non-operative treatment, with a symptomatic full-thickness rotator cuff tear were offered ARCR. Exclusion criteria were partial thickness RCT, cuff tear arthropathy and...
comorbidities precluding a general anaesthetic. All procedures were performed by the senior author (BRR).

Patients were assessed pre-operatively and at one year post-operatively using the Constant-Murley score.12 This scoring was performed by members of the senior author’s team, trained in assessment of the shoulder, in the outpatient clinic. Strength was measured using a digital dynamometer (Myometer 500N; Atlantech Medical Devices Ltd., Nottingham, United Kingdom). Measurements were performed with the shoulder abducted to 90° in the scapular plane (30° in front of the coronal plane). The loop was placed over the forearm, with the elbow in extension and the forearm pronated with the palm facing the floor. This was repeated three times and the average was recorded. The patient scored zero if he or she was unable to abduct to 90° or if the procedure was painful. Details of symptoms, duration and history of shoulder injury were collected. A total of 39 RCTs (57%) were diagnosed pre-operatively on ultrasound (USS) and nine (13%) were diagnosed pre-operative MRI. In three shoulders (4%) no cuff tear was seen on USS. The remaining 18 shoulders (26%) were not assessed pre-operatively using USS or MRI.

The operations were performed under general anaesthesia and interscalene block with intravenous cefuroxime antibiotic prophylaxis. Hypotensive anaesthesia was used when safe, aiming for a systolic blood pressure of 100 mmHg. Patients were placed in the beach chair position with the arm held in a Spider limb positioner (Smith & Nephew UK Ltd, London, United Kingdom) was used, with a standard inflation pressure of 40 mmHg. Subacromial decompression (SAD) was performed in 61 repairs (88%), using a Helicut burr (Smith & Nephew UK Ltd). Tears were classified according to the tendons involved and by size using the system of Cofield and described as either crescent or ‘U’ shaped.14 The latter often required a side-to-side suture for ‘margin convergence’.

Mobilisation was performed for all but the small tears as described by Burkhart.15,16 The anterior interval slide released tissue at the rotator interval from the supraspinatus. The coracohumeral ligament was released to improve excursion of the tendon for a tension-free repair. A posterior interval slide was added for massive contracted crescent shaped tears. Footprint preparation comprised soft-tissue debridement. Lateral fixation was performed with Fastin RC anchors double loaded with Orthocord (both DePuy Mitek EMEA). Single-row repair was performed in all cases. Anchors were placed at the margin of the articular cartilage. There were 35 single-anchor repairs and 34 double-anchor repairs. Simple sutures were used when possible, a modified Mason-Allen suture configuration was used for poorer quality tissue.17,18 The Duncan loop19 was used as the standard sliding knot. Simple knots were used if a sliding knot was not possible. In 41 cases (59%), the repair was judged to be ‘watertight’. The repair was assessed as ‘not watertight’ in 22 cases (32%) and this assessment was not recorded in six (9%). Wounds were dressed with Opsite dressings (Smith & Nephew UK Ltd) and the limb was then placed in a Polysling (Möllycke Health Care Ltd., Dunstable, United Kingdom). A range of tear sizes and tendons were operated on (Tables I and II). Long head of biceps (LHB) pathology was noted in 25 shoulders (36%). LHB procedures consisted of debridement in six cases, tenodesis in 11 and tenotomy in six.

Rehabilitation was supervised by a specialist physiotherapist and began ten to 14 days post-operatively. During this phase, passive movements and closed kinetic chain exercises were performed with the aim of restoring neuromuscular control and maintaining the ROM whilst protecting the repair. Polyslings were removed at four weeks and active assisted exercises started. The mid phase from six weeks involved progression to active exercises. The late phase from eight weeks onwards included full active movements throughout all ranges with rotator cuff strengthening and proprioceptive exercises. Specific functional activities were also addressed in the late stage. Progressions through each phase not only relied on the timeframe post-operatively but also pain and movement pattern.

Post-operatively the integrity of the repair was evaluated by USS, which was performed by one of two musculoskeletal radiologists using a 12 MHz transducer (Toshiba Aplio XG; Toshiba medical systems Ltd., Crawley, United Kingdom). With the patient sitting on a stool the long head of biceps tendon (LHBT), subscapularis, supraspinatus and infraspinatus tendons were assessed in their longitudinal and transverse axes. A re-tear was diagnosed if there was a focal full thickness defect in the rotator cuff tendon, or if it could not be visualised as a result of retraction beneath the acromion.

**Statistical analysis.** A paired t-test was used to investigate the changes in the Constant-Murley scores at one year

| Table I. Frequency of different sizes of rotator cuff tear |
|-----------------|-----------------|-----------------|
| Size            | Frequency (n, %)| Size            | Frequency (n, %) |
| Small (< 1 cm)  | 5 (22)          | Moderate (> 1 cm to ≤ 3 cm) | 17 (24.6) |
| Moderate (> 1 cm to ≤ 3 cm) | 17 (24.6) | Large (> 3 cm to ≤ 5 cm) | 29 (42.0) |
| Large (> 3 cm to ≤ 5 cm) | 29 (42.0) | Massive (> 5 cm) | 18 (26.1) |
| **Total**       | **69 (100)**    | **Total**       | **69**          |

| Table II. Tendons involved in the rotator cuff tear |
|-----------------|-----------------|
| Tendon          | Frequency (n, %)| Tendon          | Frequency (n, %) |
| Supraspinatus   | 12 (17.4)       | Supraspinatus   | 12 (17.4)       |
| Supraspinatus and infraspinatus | 53 (76.8) | Supraspinatus and subscapularis | 2 (2.9) |
| Supraspinatus and subscapularis | 2 (2.9) | Supraspinatus, infraspinatus and subscapularis | 2 (2.9) |
| **Total**       | **69**          | **Total**       | **69**          |
Post-operatively compared with the pre-operative scores. A regression test for trend was then performed on the change in scores, with RCT as the explanatory variable, to determine if the change in score was related to the size of the RCT. A chi-squared test for trend was used to determine if the probability of re-tear varied with the size of RCT.

A Kaplan-Meier plot was produced to show how the cumulative re-tear free survival probability changes with time after surgery. Further plots were stratified by history of injury, age, gender, size of tear and duration of symptoms.

Cox’s proportional hazards regression was used to investigate predictors of survival time until re-tear. The variables of interest were history of injury, age, gender, pre-operative shoulder score, size of tear, duration of symptoms, SAD procedure, and watertight repair. Univariate Cox regression models were fitted with each of these variables, entering the models as single explanatory variables. A log_{10} transformation was applied to the duration of symptoms in order to reduce the influence of outliers in this variable.

Time-dependent covariates were used to check the proportional hazards assumption.

For the Constant-Murley score at one-year linear regression modelling was used after adjusting for pre-operative score. Linear regression models were fitted with score at one-year as the outcome variable and with each of the variables of interest entering the models as single explanatory variables with pre-operative score.

A forwards model selection method (F-tests) was used in the context of multiple linear regression. Beginning with a linear regression model with no explanatory variables included, variables were added to the model in turn and only remained if they gave a significant improvement to the model goodness-of-fit. Sensitivity analysis involved using a stepwise model selection method to check the results.

The SAD variable could not be included in the multiple linear regression method, because after exclusion of patients with missing values, only one of the remaining patients did not undergo SAD.

R software v2.13.0 (R Foundation for Statistical Computing, Vienna, Austria) was used to construct the Kaplan-Meier plots. SPSS version 18 was used for all other analyses (SPSS Inc., Chicago, Illinois). The significance level was set at 5% throughout.

Results

Complete data were available for age, gender and size of RCT. Pre-operative shoulder score, ASA grade, duration of symptoms and history of injury had data missing for 14, eight, four and two repairs, respectively.

A total of 61 patients (comprising 62 repairs) attended post-operative USS assessment at a median follow-up of 14 months (1 to 50). Of these 62 repairs, re-tear was found to have occurred in 20 (32%). The probability of sustaining a re-tear was higher with increasing size of RCT (p = 0.042, chi-squared test for trend) (Table III).

All Kaplan-Meier plots showed some differences between groups, but the differences were especially clear for age (Figs 1 and 2, Table IV).

Only age at operation was significantly associated with re-tear free survival (Table IV). The risk of a re-tear occurring was a mean of 1.12 times higher (95% confidence interval (CI) 1.02 to 1.23) than the risk of re-tear in a patient aged one year younger.

Pre- and post-operative Constant-Murley scores were available for 51 shoulders. The mean pre-operative score

<table>
<thead>
<tr>
<th>Table III. Frequency of re-tear classified by size of tear</th>
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</thead>
<tbody>
<tr>
<td>Size of tear</td>
</tr>
<tr>
<td>No re-tear (n, %)</td>
</tr>
<tr>
<td>Re-tear (n, %)</td>
</tr>
<tr>
<td>Total (n)</td>
</tr>
</tbody>
</table>
was 22.5 (SD 12.1) in shoulders in male patients and 22.8 (SD 15.8) in shoulders in female patients (p = 0.939). The overall mean pre-operative score was 22.6 (SD 14.0). This increased to a mean of 58.6 (SD 19.9) at one year (paired t-test, p < 0.001). Repairs that were intact at follow-up had a mean improvement of 43 points (95% CI 5.25 to 25.7) greater than female shoulders. These multiple regression results were confirmed after stepwise model selection using the same significance level (5%) for admission and elimination of variables (n = 36).

One patient developed deep infection four weeks post-operatively and required an arthroscopic washout that revealed that the repair had failed. The infection settled following a course of antibiotics.

### Discussion

We have reported a significant improvement in the mean Constant-Murley score one year post-operatively. Statistically significant p-values were given in bold (CI, confidence interval)

Table IV. Results of Cox proportional hazards regression models investigating selected variables and their association with the Constant-Murley score one year post-operatively. Statistically significant p-values are given in bold (CI, confidence interval)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard ratio (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operative shoulder score (n = 62)</td>
<td>0.984 (0.947 to 1.023)</td>
<td>0.424</td>
</tr>
<tr>
<td>Age at operation (n = 62)</td>
<td>1.120 (1.021 to 1.228)</td>
<td>0.016</td>
</tr>
<tr>
<td>Male (n = 62)</td>
<td>0.530 (0.206 to 1.363)</td>
<td>0.188</td>
</tr>
<tr>
<td>History of injury (n = 60)</td>
<td>1.863 (0.734 to 4.729)</td>
<td>0.191</td>
</tr>
<tr>
<td>Large or massive size of tear* (n = 62)</td>
<td>0.980 (0.344 to 2.786)</td>
<td>0.969</td>
</tr>
<tr>
<td>ASA grade (1 to 4)† (n = 43)</td>
<td>-8.20 (-17.53 to 1.14)</td>
<td>0.084</td>
</tr>
<tr>
<td>Duration of symptoms (log10 transformed) (n = 45)</td>
<td>-9.02 (-21.90 to 3.86)</td>
<td>0.165</td>
</tr>
<tr>
<td>Subacromial decompression (n = 48)</td>
<td>28.41 (9.83 to 46.99)</td>
<td>0.004</td>
</tr>
<tr>
<td>Watertight repair (n = 43)</td>
<td>12.26 (0.17 to 24.88)</td>
<td>0.053</td>
</tr>
</tbody>
</table>

* reference category is small or moderate size of tear  
† ASA, American Society of Anesthesiologists

In the multivariate analysis, after forward model selection, only gender was significantly associated with the score at one year (p = 0.019). Shoulders in males were estimated to have a one-year score that was a mean 15.5 points (95% CI 5.25 to 25.7) greater than female shoulders. These multiple regression results were confirmed after stepwise model selection using the same significance level (5%) for admission and elimination of variables (n = 36).

One patient developed deep infection four weeks post-operatively and required an arthroscopic washout that revealed that the repair had failed. The infection settled following a course of antibiotics.

Table V. Results of the linear regression models investigating selected variables and their association with the Constant-Murley score one year post-operatively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operative shoulder score (n = 46)</td>
<td>0.44 (0.04 to 0.85)</td>
<td>0.031</td>
</tr>
<tr>
<td>Age at operation (n = 48)</td>
<td>-0.90 (-2.12 to 0.32)</td>
<td>0.144</td>
</tr>
<tr>
<td>Male (n = 48)</td>
<td>14.13 (3.39 to 24.87)</td>
<td>0.011</td>
</tr>
<tr>
<td>History of injury (n = 47)</td>
<td>-5.36 (-16.24 to 5.53)</td>
<td>0.327</td>
</tr>
<tr>
<td>Large or massive size of tear* (n = 48)</td>
<td>-4.58 (-16.29 to 7.13)</td>
<td>0.435</td>
</tr>
<tr>
<td>ASA grade (1 to 4)† (n = 43)</td>
<td>-8.20 (-17.53 to 1.14)</td>
<td>0.084</td>
</tr>
<tr>
<td>Duration of symptoms (log10 transformed) (n = 45)</td>
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Discussion

We have reported a significant improvement in the mean Constant-Murley score after ARCR in patients aged ≥ 70 years. However, our results suggest that within this cohort, greater age increased the likelihood of sustaining a re-tear after ARCR. It may be important to consider age when deciding whether to repair a RCT. Even so, those patients with a re-tear usually had an improvement in their Constant-Murley score, albeit to a lesser degree. Male patients achieved a better Constant-Murley score one year post-operatively than their female counterparts. The size of tear was not significantly associated with this score.

Univariate analysis showed that SAD was significantly associated with the Constant-Murley score one year post-operatively. There is a possibility that the symptomatic improvement could be solely related to the SAD. However, the study was not designed to investigate this particular hypothesis.

There was insufficient evidence of any relationship between history of injury and either re-tear free survival or the Constant-Murley score one year post-operatively.

Both open and arthroscopic RCR in older patients have been reported. Worland20 studied 69 open RCRs in patients aged ≥ 70 years. Satisfactory University of California, Los Angeles (UCLA) scores21 were achieved in 78%. None of the pre-operative variables was significantly associated with a favourable outcome.
Our finding that male patients were more likely to have a better score one year post-operatively is similar to that of Lam and Mok, who studied the outcome of open repair of massive RCTs in patients aged ≥65 years. Multiple regression analysis revealed that female gender, longer duration of symptoms and higher ASA grade were related to a poorer outcome. However, there were no pre-operative scores for comparison. They also found no relationship between the Constant-Murley score and patient age.

Satisfactory outcome following a mini-open repair in patients aged > 65 years has been reported, restoring the simple shoulder test (SST) and Constant-Murley scores to a level similar to that of individuals with an intact rotator cuff. Also, in a series of 97 mini-open RCRs in patients aged ≥62 years and at a mean follow-up of 35 months, Grondel et al reported a good or excellent result in 87%, with five patients suffering re-tears. Patients with a massive tear had a significantly worse follow-up UCLA score. They also found no significant difference between the older and younger groups of patients in terms of UCLA score. There have been few studies of ARCR in older patients. Rebuzzi et al reported the outcome of 54 patients aged > 60 years. All components of the UCLA score were significantly improved at a minimum follow-up of two years, with no significant differences in scores between differing sizes of tear or in patients of different age. There was no attempt to adjust for other variables and no imaging was reported.

Verma et al reported the outcome of ARCR in 39 patients aged ≥70 years at a mean follow-up of 36 months; there were only seven large or massive tears. The mean visual analogue pain scale (VAS), American Shoulder and Elbow Surgeons score (ASES), SST and forward flexion all increased significantly. No imaging was performed to confirm that the repair was intact. The mean Constant-Murley score at final follow-up was 78 in men and 66 in women. These findings were similar to those of Constant-Murley score at final follow-up was 78 in men. At six months 42% had a re-tear. There were only six massive tears, with a 100% rate of re-tear. Isolated small and medium supraspinatus tears had significantly better tendon healing compared with the massive or retracted tears. The mean Constant-Murley score was significantly lower in patients with a re-tear. This agrees with our findings. Although Charousset et al reported a 52% healing rate in these patients, there was no analysis of the effect of age.

Oh et al reported the outcome of 47 mini-open and 130 ARCRs in patients with a mean age of 60 years. Multiple regression analysis revealed only the degree of retraction of the tear and the fatty degeneration of infraspinatus were significantly related to integrity of the cuff on CTA. Interestingly, the age of the patient was not found to be significantly related to either the integrity of the cuff or the functional outcome.

We hypothesised that patients with a history of trauma may be different to those with a degenerative tear in that the traumatic tears may have better healing potential. However, we were unable to find any relationship with re-tear free survival. This is in keeping with the findings of others. Our study had a higher proportion of large and massive RCTs than in the studies of ARCR that have previously been discussed. Our rate of re-tear was 63% for massive tears, similar to rates of 31% and 94%, which have been reported elsewhere. Our post-operative rehabilitation regime was graduated in order to avoid shoulder stiffness and minimise muscle atrophy. We did not feel that this regime contributed to re-tears. We are not aware of any strong clinical evidence in the literature that a longer period of shoulder immobilisation is beneficial to either clinical outcome or tendon healing. Randomised trials have not found any significant differences in re-tear rates between early passive motion and longer shoulder immobilisation regimes.

The optimum technique for repairing RCTs has been much discussed. Double-row anchor configurations are biomechanically superior to the single-row repairs used in this study. However, this has not been borne out in clinical studies. A recent meta-analysis showed a non-significant trend towards better functional outcome and a lower failure rate in double-row compared with single-row repairs. We used a modified Mason-Allen suture in tendons of poorer quality. The advantages of this suture in ARCR are unclear.
USS imaging to assess the integrity of the repair. A recent meta-analysis reported the sensitivity and specificity of USS in diagnosing full thickness RCTs to be 0.96 and 0.93, respectively.\textsuperscript{50} A further strength of our study is that all sizes of RCT were repaired. Our statistical analysis considered re-tear free survival, which removes the possibility of bias due to differences in duration of follow-up.

Limitations include the lack of a control group, blinding or randomisation and that scoring was carried out by members of the treatment team. In addition, although the size of our cohort was large in comparison to other studies, it was not large enough to support reliable and precise estimates of effect size in multiple regression analysis with several variables. In particular, there were insufficient data to perform a multiple Cox regression for re-tear free survival. A total of five patients recorded Constant-Murley scores some time after one year. They were included in a sensitivity analysis and our conclusions were unchanged. We have no reason to suspect that the missing values observed in our study are related to outcome.

In conclusion, ARCR in patients aged ≥ 70 years is a successful procedure. Approximately two-thirds of repairs remained intact after one year. Age appears to be an important factor associated with the probability of a re-tear. Male patients were more likely to have a better Constant-Murley score one-year post-operatively. We would recommend further studies of ARCR in this patient group to clarify risk factors for re-tears and to assess the long term benefits.

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References


The London 2012 Summer Olympic Games: an analysis of usage of the Olympic Village ‘Polyclinic’ by competing athletes

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ABSTRACT

Background The London 2012 Summer Olympic Games involved 10 568 elite athletes representing 204 competing nations. To manage the varied healthcare needs of this diverse population, a Polyclinic was constructed in the athletes’ village.

Aim This work aims to summarise the usage of the Polyclinic by competing athletes and the facilities available to them.

Methods All Polyclinic encounters were entered into a database from which data were exported for the time frame 28 July–12 August 2012, inclusive to cover the first to last full day of competition. Only Polyclinic data involving accredited athletes were analysed. All types of encounters were collected for analysis, not just sports-related issues.

Results There were a total of 3220 encounters within the Polyclinic. This figure combines medical consultations, radiology/pathology investigations and prescriptions dispensed. Of these 3220 encounters, there were 2105 medical consultations; musculoskeletal comprised the greatest number (52%), followed by dental (30%) and ophthalmic (9%). The most frequently used imaging modality was MRI and diagnostic CT was used the least. After correction for multiple entries, Africa provided the largest proportion of athletes attending the Polyclinic (44%) and Europe the least (9%). Peak usage of all facilities was seen around days 9 and 10 of competition, reflecting the busiest time of the competition and the largest number of athletes in the village.

Conclusions The Polyclinic managed a wide variety of both sports-related and non-sports-related injuries and illnesses. The breadth of specialists available for consultation was appropriate as was the ease of access to them. The radiology department was able to satisfy the demand, as were the pharmacy and pathology services. We would recommend a similar structure of facilities and available expertise in one clinic when planning future mass participation sporting events.

BACKGROUND

The London 2012 Summer Olympic Games involved 10 568 elite athletes competing for 204 separate National Olympic Committees (NOC’s). It was of comparable size to that of previous Summer Games1,2 but over twice the size of either the 2002 Manchester Commonwealth Games (3679 participants)3 or 1948 Summer Olympics (4104 participants) previously held in London.4 To manage the varied healthcare needs of those involved, a polyclinic was constructed on the athletes’ village site in Stratford, East London. The London Olympic Games Organising Committee (LOCOG) aimed to provide a dedicated on-site medical facility to be staffed by volunteer experts across multiple sports-related specialties similar to that of previous Games.2,3 Their aim was to manage the majority of Games-related healthcare issues internally in an attempt to provide an optimal level of care and avoid pressure on local hospitals and other healthcare providers.

Protection of the health of competing athletes remains a key objective during Olympic Games and forms an important part of the International Olympic Committee’s (IOC) agenda.2,6,7 One of the main aims of the IOC is to provide freely available healthcare to all athletes during Games as well as institute safeguarding measures to protect athletes during competition. It is accepted that the healthcare needs of elite athletes is complex and extends beyond the immediate injuries sustained in competition. Furthermore, the incidence of injuries and illnesses is known to vary according to individual sports and by the athlete’s country of origin.8,9

This paper aims to summarise the utilisation of resources within the clinic as well as comment more generally on patterns of usage by different nations. In presenting data on only those competing, it will provide a novel insight into the health-seeking behaviours of a diverse population of elite athletes. The scale of the facility is detailed as well as the equipment and personnel needed to service such a large event involving worldwide participants from varied domestic healthcare systems.

METHODS

The Polyclinic was situated within the Athletes’ village in Stratford, East London and was in proximity to the main Olympic Park. It functioned as a small hospital and was arranged over five fully integrated floors. In the basement a small pool, zero gravity treadmills and massage tables provided rehabilitation and recovery facilities. The ground floor was the administrative centre with a reception, pharmacy and offices. There was also an acute care department including three beds for overnight admission. The first floor was the main treatment hub and included consultation rooms (sports medicine, general medicine, therapeutic radiology), a physiotherapy department and a research centre.
The second floor was used for sports medicine and podiatry, and the top floor contained large dental and optometry departments as well as meeting rooms.

The Polyclinic was staffed entirely by volunteers and included general physicians, sports medicine doctors, dentists, ophthalmologists, optometrists, physiotherapists, podiatrists and sports massage therapists. Other services included a dispensing pharmacy and fully functioning radiology department staffed by musculoskeletal radiologists. In addition, specialists could be called upon to visit athletes in the Polyclinic, and there was ready access to extensive services in the nearby Homerton and Royal London hospitals.

All medical encounters were entered into a specially designed database (Atos IT Services Limited, London, UK), which was available to all staff working in the Polyclinic. The data inputted included general athlete demographic information, history of presenting complaint, past medical conditions, examination findings and investigations requested. The pharmacy and medical departments both used the same system and therefore allowed for accurate continuity of care and confidential data collection. The database was password protected and any paperwork containing athlete information (requests or results) was destroyed after the Games to ensure that confidentiality was maintained.

Comprehensive blood analysis services were provided at the Polyclinic throughout the Games period. This testing was separate from the doping blood analysis, which was performed independently by the World Anti-Doping Agency in a separate facility. The pharmacy department was only able to dispense medication prescribed by a doctor within the Polyclinic. Private prescriptions from outside were not dispensed. It was stocked with a wide range of drugs in line with current antidoping policy.

The radiology department was equipped with 1.5 and 3 Tesla wide bore MRI scanners, Discovery 750 HD 64 slice CT scanner, 2 Logic E9 ultrasound units and an XR656 wireless digital x-ray system. Integrated radiology information system (RIS) and Picture Archiving and Communication System were set up with facilities for voice recognition to generate and store dictated reports. Referrals for radiological investigations were accepted directly from both team doctors and LOCOG doctors based at the polyclinic and at the event venues. Radiology requests were entered into the RIS system and this dataset was used to obtain imaging statistics.

Experienced musculoskeletal (MSK) radiologists reported all radiological investigations apart from general ultrasound examinations that were carried out by trained sonographers. Interventional procedures were performed both under CT and ultrasound guidance by MSK radiologists. During the Games, the majority of investigations were performed on athletes, followed by team officials and then the workforce. Athletes still competing were given preference over athletes who had finished their events. Requests for MRI and ultrasound were still being received on the closing day of the Polyclinic.

Data were exported from Atos and RIS for the time frame 28 July–12 August 2012, both days inclusive. Although the football competition started prior to this date, the opening ceremony was held on 27 July and the first full day of the competition started on 28 July.

We defined ‘Polyclinic encounters’ as any accredited athlete seeking medical attention for injuries and illnesses sustained in both competition and training during the London Olympic Games. This included all medical consultations, pharmacy, pathology and radiology investigations/procedures. Non-athletes such as coaches, officials and other NOC staff seeking medical attention were excluded from the analysis. Encounters taking place in any medical facility other than the Polyclinic, including in the field of play venues, were excluded as this work relates only to usage of the Polyclinic.

Data analysis and correction for duplicate data were performed using Excel, version Mac OS X (Microsoft, Redmond, Washington). Countries have been grouped into their respective continent based on the United Nations Statistics Division classification. The proportion of attendances for individual athletes was calculated by dividing the number of individuals who were seen in the polyclinic by the total number of individual attendances. We present radiology data with means and SD.

RESULTS
Usage of polyclinic departments
Medical consultations
General
Medical consultations included interactions with any of the healthcare specialists, that is, general physicians, sports medicine doctors, dentists, ophthalmologists, optometrists, physiotherapists, podiatrists and sports massage therapists. In total, 2105 medical consultations took place over the 16-day period. These data are summarised in figure 1 and illustrate a peak attendance around days 9 and 10 of the competition when over 250 consultations took place each day (mean 201 daily consultations).

Musculoskeletal (52% of all encounters) and dental care (30%) were the most common categories under which consultations were logged. Consultations covered a wide range of medical specialties and were not limited to only exercise-related complaints (table 1).

Musculoskeletal encounters
The subdivision of complaints within the category is illustrated in table 2. On a review of the clinical records, the 31% who were logged as involving ‘multiple locations’ most commonly related to athletes seeking physiotherapy or sports massage with multiple muscle tension points.

Radiology
A wide range of diagnostic investigations and imaging-guided interventional procedures were performed on athletes during the games (figure 2), with MRI constituting the greatest component of daily workload (mean 34, SD 9). MRI showed a generally upward trend, peaking on day 9, with 50 MRIs before steadily declining to 25 MRIs on day 16. Diagnostic ultrasound peaked on the 10th day with 18 examinations, before coming...
down to 8 examinations on day 16. Compared with MRI and ultrasound, the number of plain x-rays performed had a slightly delayed peak, on day 13 with 24 examinations. A total of 36 diagnostic CT scans were performed.

In contrast to the trends observed for MRI, ultrasound and plain films, the demand for interventional procedures was steady throughout the Games. Imaging-guided interventional procedures on peripheral extremities such as corticosteroid and local anaesthetic injections for indications such as tenosynovitis and bursitis were performed under ultrasound guidance. Spinal interventions, for example, selective nerve root blocks, facet joint and epidural injections were performed under CT fluoroscopy.

The maximum number of interventional procedures in a day was 6 on days 1 and 7 (figure 2). Although diagnostic CT was a less utilised resource, the use of CT fluoroscopy for spinal interventional procedures and in evaluating possible bony stress fractures was thought to be invaluable. In this application, CT fluoroscopy had a major influence on future participation and performance outcome during the competition.

Pathology and pharmacy
A total of 290 pathology tests were performed. These were performed at a steady rate throughout the Games with an average of 19 pathology tests performed daily (figure 3). In total, 930 prescriptions were dispensed with a mean of 62 prescriptions each day. In a similar pattern to the peak in demand for other services, a rise in prescriptions was seen on day 10 when 122 prescriptions were processed.

Distribution of encounters by continent
Over the 16-day period under scrutiny, there was a total of 3220 encounters within the Polyclinic (table 3). This table combines usage of all services within the facility such as medical consultations, radiology/pathology investigations and prescriptions dispensed. Each encounter has been further analysed to establish the continent of origin of the athlete.

The greatest proportion of total encounters was from athletes competing for African nations (28%) followed by athletes from America (26%). Once corrected for duplicate encounters from the same athlete, Africa had the highest proportion of athletes seen at the Polyclinic (44%), and Europe the least (9%).

DISCUSSION
This work highlights the broad range of diagnostic and therapeutic services available to athletes during the London 2012 Olympic Games. Peak usage of many of the facilities was seen around days 9 and 10 of the competition (5 and 6 August 2012). This is when there was the greatest number of event finals occurring\textsuperscript{11} and the athletes’ village was at its busiest. As expected, most consultations were musculoskeletal in origin but...
enabled an efficient working environment prior to the start of the Games. This involved an induction and orientation to the building and undergone a comprehensive recruitment and selection process. Despite being serviced entirely by volunteers, staff had busier services such as physiotherapy, sports massage and radiologically; however, minimal waiting time was seen for some of the being seen. Staff often were accompanied by their NOC Oceania cohort. Attendances would constitute a greater proportion of the small number of athletes (670); therefore, individual team members (30%). This reflects the fact that Oceania fielded the smallest number of athletes (670); therefore, individual attendances would constitute a greater proportion of the small Oceania cohort.

Athletes were able to self-present to the Polyclinic and would attend the appropriate department and rarely had a significant delay in being seen. Staffing levels appeared to meet the demands effectively; however, minimal waiting time was seen for some of the busier services such as physiotherapy, sports massage and radiology. Despite being serviced entirely by volunteers, staff had undergone a comprehensive recruitment and selection process involving an induction and orientation to the building and working environment prior to the start of the Games. This enabled an efficient working environment right from the start of the Games and limited any start-up issues. Daily work force meetings at the start and end of each shift further reinforced good communication and working relations among staff from different departments in the Polyclinic.

Efficient assimilation and storage of medical encounter data were crucial throughout the Games. Workstations connected to the Games network were available in all medical venues including all fields of play to allow timely data input. This meant that records were kept contemporaneously and could be referred to during successive visits for the same individual. The Atos database provided an effective platform for these data to be securely stored and contained relevant data fields to be comprehensive and appropriate.

**Table 3** Distribution of Polyclinic encounters by athlete continent of origin with correction for duplicate attendances

<table>
<thead>
<tr>
<th>Continent</th>
<th>Total competing athletes</th>
<th>Polyclinic encounters</th>
<th>Proportion of total encounters (%)</th>
<th>Correction for duplicates</th>
<th>Proportion of total encounters</th>
<th>Proportion of athletes seeking attention (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>898</td>
<td>922</td>
<td>28.6</td>
<td></td>
<td>393</td>
<td>24.8</td>
</tr>
<tr>
<td>Asia</td>
<td>1757</td>
<td>520</td>
<td>16.1</td>
<td></td>
<td>249</td>
<td>15.7</td>
</tr>
<tr>
<td>Europe</td>
<td>5230</td>
<td>718</td>
<td>22.3</td>
<td></td>
<td>465</td>
<td>29.4</td>
</tr>
<tr>
<td>America</td>
<td>2009</td>
<td>843</td>
<td>26.2</td>
<td></td>
<td>273</td>
<td>17.2</td>
</tr>
<tr>
<td>Oceania</td>
<td>670</td>
<td>217</td>
<td>6.7</td>
<td></td>
<td>204</td>
<td>12.9</td>
</tr>
<tr>
<td>Independent Olympic Athlete</td>
<td>4</td>
<td>0</td>
<td>0.0</td>
<td></td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>10568</td>
<td>3220</td>
<td>100</td>
<td></td>
<td>1584</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Practical implications and further research**

The Polyclinic provided an appropriate breadth and accessibility of expertise and facilities to safeguard athlete health at the Games. Although staffed entirely by volunteers, a high level of care was delivered and the aims of LOCOG and the IOC were achieved. The healthcare of elite athletes remains a key priority in the organisation of major sporting events, although the specific impact of this can be hard to predict. The work here provides clear details of what to expect and what is required for those planning similar future endeavours.

There are several other methods for estimating healthcare needs of such a population, for example, the WHO health impact assessment (HIA). The HIA was found to be a useful tool in planning the public health agenda for the 2014 Commonwealth Games but is generally considered to lack robust evidence to consider it reliable in predicting impact accurately.

Alternative strategies to monitor an athlete’s health include the collation of epidemiological data on injuries and illnesses sustained during major championships. There are many examples of this in the literature to include youth and adult cohorts participating in a wide range of sporting pursuits. The longitudinal evidence acquired from successive championships has increased the scientific strength of these studies, making them of vital importance in the monitoring of athlete health and wellbeing. Work by the IOC has emphasised the importance of injury surveillance and has since 2008 monitored athlete’s injury (and later illness) risk in each Summer and Winter Games.

The work presented highlights those health issues which could not be managed internally by the NOC’s own medical staff. Examples include: access to pharmacy medication, use of specialist rehabilitation equipment, diagnostic imaging or...
obtaining specialist medical opinion. This may be due to a lack of medical personnel travelling with the team or the resources available to them domestically or at the Games. Teams with a small number of athletes are limited in additional personnel travelling with the team and will often choose coaching staff over a team doctor or physiotherapist.

It is acknowledged, however, that long distance travel is an independent risk factor for illness risk among elite athletes in competition. In contrast, several of the larger teams choose to travel with extensive medical support diminishing the need to utilise Polyclinic services. These support staff are often present at pre-Games training camps and their own medical facilities could be seen throughout the athletes’ village. It is noted, however, that America still comprised 26% of all Polyclinic utilisation during the Games and these met the demands of this unique population of elite athletes.

In summary, this work provides details of the patterns of daily usage and the facilities required by elite athletes attending the London 2012 Olympic Games. Planning and provision of healthcare at an Olympic Games is a complex task which we feel was adequately achieved at these Games. The pattern of healthcare demands at this event will provide invaluable information for planning future mass participation sporting events. It is important to remember that this is only one facet of healthcare provision at an Olympic Games. It must be combined with field of play data as well as ‘illness and injury’ data such as that collected by the IOC to produce a more complete picture of all medical needs during these events.

CONCLUSION
The London 2012 Summer Olympic Games was the largest mass participation sporting event to be held in the UK. It saw over 10,000 competing athletes from 204 separate nations. Much of these athletes’ healthcare needs were provided by the Polyclinic located in the athletes’ village. A wide range of diagnostic and therapeutic services were provided by the Polyclinic and these met the demands of this unique population of elite athletes. Provision and safeguarding athlete health is of paramount importance to the IOC and this was achieved through the role of the Polyclinic.

What are the new findings?

- The London 2012 Olympic Games was the largest sporting event in the UK to date and was over 2.5 times the 1948 London Olympics.
- In total, 10,568 elite athletes participated from 204 separate nations.
- This is the first paper to categorise attendance by continent of origin and analyse Polyclinic usage using this method.
- Peak usage is expected by days 9 and 10 of the competition, coinciding with the greatest number of event finals and number of athletes resident in the village.

Correction notice This article has been corrected since it was published Online First. The affiliation address for DPG has been corrected.

Competing interests None.

Provenance and peer review Commissioned; internally peer reviewed.

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The London 2012 Summer Olympic Games: an analysis of usage of the Olympic Village 'Polyclinic' by competing athletes

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Amateur boxing in the last 59 years. Impact of rules changes on the type of verdicts recorded and implications on boxers’ health

Massimiliano Bianco,1 Mike Loosemore,2 Gianlorenzo Daniele,1 Vincenzo Palmieri,1 Marcello Faina,3 Paolo Zeppilli1

ABSTRACT

Background/aim Several changes have occurred in Olympic boxing (OB) in the last few decades, influencing the results in official competitions. The aim of this study was to assess how the evolution of rules changed the rate of the results that can influence boxers’ health.

Methods From a web-research, the results of OB tournaments from 1952 to 2011 were reviewed (29 357 bouts). For each event, rate of knockout (KO), referee-stop contest (RSC), RSC-Head (RSCH), RSC-Injury (RSCI), RSC-Outclassed (RSCO), abandon, disqualification and points decisions were recorded. In our analysis we investigated the changes that occurred after the introduction of the standing-count rule (1964), mandatory head guard (1984), computerised scoring system (1992), RSCO (2000–2009) and modification of bout formula 3×3 min rounds (3×3, until 1997, 5×2 min rounds (5×2) until 1999, 4×2 min rounds (4×2) until 2008, 3×3 from 2009).

Results The most important results were: (1) an RSCI rate increase (0.72–2.42%, p<0.03) after the standing-count rule; (2) a lower RSCI (0.60%, p<0.001) and higher RSCH (1.31–4.92%, p<0.001) and RSC (9.71–13.05%, p<0.003) rate with mandatory head guard; (3) a KO rate reduction (6.44–2.09%, p<0.001) with the computerised scoring system; (4) an RSC (13.15–5.91%, p<0.05) and RSCH (4.23–1.41%, p<0.001) rate reduction comparing 5×2–4×2 bouts.

Conclusions In the last six decades, along with rule changes in OB, a clear reduction of health challenging results was observed. In the near future, older rules will be adopted (no head guard and a manual scoring system). Continued medical surveillance is important to ensure that new rule changes do not result in poor medical outcomes for the boxers.

INTRODUCTION

Boxing is an ancient sport; wall paintings from Ethiopia and ancient Egypt suggest that it is well over 4000 years old. Boxing was first introduced into the ancient Olympic Games in 688 BC.1 Boxing as we know it today developed in England in the 18th and 19th centuries. In 1814, to regulate the sport, the London prize fight rules were introduced and, in 1867, the Queensbury rules were first published. The first amateur contests took place in 1860 and the amateur boxing Association started in London in 1880.2 Since this time the two codes have diverged: professional boxing (based in the tradition of prize fighting) has several sanctioning bodies which make the rules and a multitude of champions and belts, while amateur boxing is regulated only by the Amateur International Boxing Association (AIBA), an International Federation within the International Olympic Committee (IOC). The IOC has sanctioned contests at Olympic Games since 1904 (St Louis). In the last century, several changes occurred in amateur boxing not only to increase the safety of the boxers, but also to meet audience and media expectations. The most important rule changes in the last few decades are shown in figure 1.

Although international amateur boxing is a well-regulated sport practised in many countries worldwide, there are still concerns about safety and some medical organisations call for a ban on boxing.3–6 However, at this time there is no strong scientific evidence that amateur boxing is associated with serious health consequences and, in particular, with chronic traumatic brain injury.7–8 As a result, amateur boxing has been defined as a safe sport.9 A surrogate measure of the acute consequences of boxing can be made from looking at the results of boxing contests, particularly those which were stopped before the scheduled rounds had been completed. A knockout (KO) is recorded if a boxer cannot continue within 10 s of a blow from an opponent. If the referee decides that the boxer is unable to defend himself adequately and is getting or may get injured, then a referee-stop contest (RSC) decision is taken. Where this occurs from a blow to the head, then a RSC head (RSCH) decision is recorded. If an injury occurs to a boxer (ie, a dangerous cut, a fracture, a dislocation, etc) then, together with the ringside doctor, the referee can stop the contest and the recorded decision is RSC injury (RSCI). Finally, from 2000 to 2009 the RSC outclassed (RSCO) decision was recorded when the points’ gap between the two contenders was 20 points, suggesting that one athlete was outclassing the opponent.

The aim of this study was to assess how the evolution of rules in modern Olympic boxing has influenced, and continues to influence, the prevalence of one result over another paying particular attention to decisions that can influence boxers’ safety and health. To test this hypothesis the results of official amateur boxing tournaments held in the last 59 years were reviewed.

MATERIALS AND METHODS

From a worldwide web search10–12 the results of official amateur boxing tournaments held from January 1952 to December 2011 (59 years) were reviewed. These tournaments included 15 Olympic...
Figure 1  Major rule changes in amateur boxing from 1952 to 2011. In the upper part of the panel the bout length formula has been indicated. In the upper and lower parts are shown the different subgroups in which the boxing bouts were divided for the analysis. RSCO, referee stops contest outclassed.

Games, 14 World Championships, 89 Continental Championships, 52 International Tournaments (including Olympic qualifications, World Cups, Military World Championships, Commonwealth Games, Mediterranean Games, Pan-American Games) and 99 National Championships for a total of 269 tournaments. Only when complete results were present (198 tournaments), the event was included for further analysis. For each competition, we collected the rate of KO, RSC, RSCH, RSCI, RSCO (RSCO, from 2000 to 2009), contest abandoned, disqualification and points decisions. Until 1970 the technical KO decision was adopted in the same circumstances as RSC verdicts, in view of this technical KO was included with RSC for statistical analysis.

Our analysis mainly investigated changes which occurred in the rate of the RSC, RSCH, KO, decisions that can affect the RSC for statistical analysis. RSCO verdict abolition (3×3 new).

RESULTS

Statistical analysis

All data are expressed as mean value±SD unless indicated. The 95% CIs, moreover, are shown. Statssoft Statistica V6.0 was used for the analysis. All data showed a normal distribution, estimated by Shapiro-Wilk’s test. An analysis of variance was conducted and, when a significant difference was observed, a Student’s t test for unpaired data (comparing two groups) or post hoc analysis for multiple comparison (more than two groups), was used. Differences were considered statistically significant when \( p \leq 0.05 \).

To analyse how the introduction of the standing count rule in 1964 could have influenced the kind of decisions, 3×3 old-old contests (ie, from 1952 to 1963) were compared with 3×3 old bouts (ie, from 1964 to 1984). No further comparisons were drawn, as other newer rules could have effect on the rate of different decisions.

When investigating how the mandatory head guard influenced the contest, 3×3 old-old and 3×3 old bouts (separately and taken together) were compared with the 3×3 head guard group (ie, from 1984 to 1997).

The introduction of the computerised scoring system was investigated comparing the subgroup 3×3 head guard no score-machine, with 3×3 head guard score-machine inside the bigger group 3×3 head guard.

To analyse the impact of RSCO on the kind of verdicts, the 4×2 RSCO group was compared with 4×2 no RSCO, 3×3 head guard and 3×3 new groups.

In order to evaluate how the different length bout formulas changed the kind of decisions over the time, all the subgroups (3×3 old-old, 3×3 old, 3×3 head guard no score-machine, 3×3 head guard score-machine) after the introduction of the computerised scoring system in 1992;

D. the sum of the previous three groups, including all the bouts competed with the old-time 3×3 formula (3×3 total old);
E. 1997–1999, when the 5×2 formula was adopted (5×2);
F. 1999–2009 (4×2), dividing this group into two subgroups (4×2 no RSCO and 4×2 RSCO) following the introduction of RSCO verdict in 2000; G. 2009–2011, coming back to the old 3×3 formula and RSCO verdict abolition (3×3 new).
2.42±2.51% (CIs 1.42% to 2.88%) in 3×3 old contests. In the following years, also after the introduction of other rules, the RSCI rate was lower: 0.60±0.98% in 3×3 head guard (CIs 0.17% to 1.17%), 1.17±1.88% in 5×2 (CIs 0.04% to 2.31%), 0.95±1.35% in 4×2 no RSCO (CIs 0.38% to 1.88%), 1.33±1.70% in 4×2 RSCO (CIs 0.93% to 1.76%) and 1.45±1.12 in 3×3 new (CIs 0.98% to 1.94%).

Mandatory head guard (1984)

After the introduction of mandatory head guard, there was a significant reduction of RSCI (from 2.04±2.35% in 3×3 old-old+3×3 old, CIs 1.26% to 2.47%, to 0.60±0.98% in 3×3 head guard, CIs 0.17% to 1.17%, p<0.001) and KO (from 6.31±5.65% in 3×3 old-old+3×3 old, CIs 5.45% to 8.41%, to 3.78±3.99% in 3×3 head guard, CIs 2.23 to 4.71%, p<0.03) rates, balanced, however, by a higher rate of RSCI (from 3.13±4.05% in 3×3 old-old+3×3 old, CIs 0.19% to 2.06%, to 4.92±5.31% in 3×3 head guard, CIs 3.99% to 4.57%, p<0.001) and RSCI (from 9.71±5.72% in 3×3 old-old+3×3 old, CIs 8.98% to 12.66%, to 13.05±7.77% in 3×3, CIs 9.01 to 15.39%, p<0.03). Taking together these results, a significant (p<0.04) increase in the rate of contests ended before the time limit (as the sum of RSC, RSCH and KO rates) was observed, rising from 17.33±8.34% in 3×3 old-old to 20.96±2.35% in 3×3 head guard, CIs 14.69% to 22.62%, p<0.001) and RSCI (from 1.31±4.05% in 3×3 old-old+3×3 old, CIs 0.19% to 2.06%, to 4.92±5.31% in 3×3 head guard, CIs 3.99% to 4.57%, p<0.001) and KO (from 6.31±5.65% in 3×3 old-old+3×3 old, CIs 5.45% to 8.41%, to 3.78±3.99% in 3×3 head guard, CIs 2.23 to 4.71%, p<0.03) rates, balanced, however, by a higher rate of RSCI (from 3.13±4.05% in 3×3 old-old+3×3 old, CIs 0.19% to 2.06%, to 4.92±5.31% in 3×3 head guard, CIs 3.99% to 4.57%, p<0.001) and RSCH (from 5.33±5.19%, CIs 4.23% to 6.19% to 1.58±1.48%, CIs 0.65% to 2.44%) was observed, with no significant changes in all the other decisions' rate.

Computerised scoring system (score-machine, 1992)

Following some scandals in point decisions, in 1992 the computer scoring system was adopted. In the group 3×3 head guard, after the introduction of the score-machines' system, there was a significant (p<0.001) reduction of KO rate changing from 6.44±4.67 (CIs 4.30% to 7.53%) to 2.09±2.33% (CIs 0.98% to 1.94%).

RSCO verdict (2000)

From 2000 to 2009, a mean rate of 15.49±11.21% (CIs 12.13% to 17.60%) of contests ended by the new RSCO rule. Consequently, comparing 4×2 no RSCO with 4×2 RSCO groups, the rate of bouts ended by points decreased (p<0.0001) from 82.56±8.73% (CIs 78.51% to 85.81%) to 69.86±12.29% (CIs 67.13% to 72.94%). All other differences met after the introduction of RSCO are summarised in table 1. Noteworthy are the significant reduction of RSC, RSCH, KO and their sum with the new rule. Moreover, no significant change in the rate of contests ended before time limit was observed in comparison with the 3×3 new formula.

Bout length formula

Comparing the 3×3 total old group (ie, from 1952 to 1997) with the new 5×2 formula, a significant (p<0.03) reduction of KO rate (from 3.33±5.19%, CIs 4.23% to 6.19% to 1.58±1.48%, CIs 0.65% to 2.44%) was observed, with no significant changes in all the other decisions' rate.

Comparing the 3×3 new group to the global 4×2, no changes were observed, points decisions’ rate apart; similar results were observed comparing 3×3 new with 4×2 RSCO groups (table 1). From the comparison of 5×2 group with 3×3 new, instead, a significant rate reduction in RSCI, RSCH, KO and their sum was observed with the comeback to the 3×3 formula (table 1).

Finally, a comparison of the new formula 3×3 new with all the previous groups with the same bout length is summarised in table 2.

DISCUSSION

Boxing is an ancient sport, with a worldwide following. At the last Olympic Games (London 2012), boxing was represented by 79 countries with a total of 286 athletes (36 of whom were...
women, competing for the first time at the Olympics13 and 194 national federations (of 205 recognised National Olympic Committees) are currently affiliated to AIBA.14

The medical community expresses several concerns about boxing. Independent from the ethical considerations of boxing, is boxing unacceptably harmful for athletes? Since the first decades of the last century, some reports highlighted the risk of traumatic brain injury in former boxers, appearing both as cognitive impairment and parkinsonism.15-18 However, all these reports referred to single cases or to very few athletes competing many years ago (in the late 19th or the first decades of 20th century), when there were fewer safeguarding rules.

At the beginning of the last century, each boxing match could last dozens of rounds (until the bout was abandoned or the KO of one competitor). At this time, boxers fought with bare knuckles or with very light gloves (2–6 ounces, that is 56.70–170.10 g instead of 10 ounce gloves, that is 283.50 g currently used), without a gum-shield and with no kind of medical check. Most of these reports refer to former professional boxers, many of whom had hundreds of contests.

When medical literature has been systematically reviewed, no strong evidence clearly linking amateur boxing with chronic traumatic brain injury was found.7-8 The AIBA has been very mindful of boxers' health and through several rules' changes introduced over the last six decades, boxing has become safer. In the London 2012 Olympics, of 272 boxing matches, there was no KO, RSC, and RSCI decision, with only four bouts ended by RSC (1.5%).

At the beginning of our analysis (Helsinki Olympic Games in 1952) amateur boxers used to compete in three rounds of 3 min each, without any head guards and less emphasis on safety, such as the standing count rule, RSCO decision and more detailed medical checks.

In the 1952 Games, the rate of KO was 17.1%, compared with the London 2012 Olympics (0%) and to the currently used rules (0.7±0.9% from 2009 to 2011). However, in Helsinki 1952 there was no technical knock-out decision (that means no RSC and RSCI), suggesting that the referee did not end the contest until the boxer was knocked out. Of interest, neither the sum of RSC, RSCI and KO verdict rate in the last Games (1.5%), nor the mean value recorded in our analysis from 2009 to 2011 (7.9±4.8%) was similar to the Helsinki results.

The first important modification to the rules of amateur boxing took place in 1964 when the standing-count rule was adopted: the referee was allowed to start an 8 s count if a boxer was in difficulties for any reason (particularly after a blow by the opponent), without the boxer having been knocked to the canvas. Even if this rule was adopted with the purpose of safeguarding boxers' health, our analysis showed a minor and not significant reduction in KO rate (from 7.6% to 5.9%), with other results of medical interests substantially unchanged, but an unexpected significant increase (table 2 and figure 2) of matches ended due to medical reasons (mainly lacerations). Only after the introduction of the mandatory head guard in the 1984 Olympics did the RSC reduce, it was clear that the introduction of the head guard reduced facial cuts by up to 90%.9-19 The mean rate of RSCI decisions showed a 3.3-fold reduction after the adoption of mandatory head guard and KO rate also significantly decreased balanced, however, by a higher rate of RSC and RSCI (table 2; figure 2). Taking together these results, a significant increase of the rate of contests ended before the time limit (as the sum of RSC, RSCI and KO rates) was observed, rising from 17.3% to 21.8%, even if this difference is partly blinded by the overlap of their CIs (16.4% to 21.3% and 14.7% to 22.6% after head guard introduction). One can hypothesise that the boxers, feeling more protected by the head guard, exposed themselves to blows that before the introduction of head guards, they would have avoided. It may also be the case that the new rules allowed the referee to stop the contest early before harm could befall a boxer.

There is a limited evidence demonstrating that boxing head guards reduce the impact force to the athletes' head.20-21 Some coaches, moreover, believe that the head protector may be detrimental to boxers' health, as it can obscure peripheral vision not allowing a boxer to defend lateral blows.22 It is important to recognise that even wearing head guards, amateur boxers still have the potential to suffer significant brain injury ranging from intracranial trauma to changes in brain cellular biomarkers post-fight.23 It is not clear if removing head guards would make any difference to such events. For these reasons, and to meet media and audience expectations (the head guard makes all the boxers quite similar and anonymous), the head guard will not be mandatory in international amateur boxing from 2013.22 It will be important to monitor this change, not only to see if the number of KO and RSCI increases, but also to see if the number of RSCI increases due to cuts. Our figures would predict that KO and RSC and RSCI will remain the same but RSCI will increase.

In 1992, following some well-publicised scandals in point decisions, a computerised scoring-system was adopted. The new rule changed the sport. It was more effective to land clear (usually single) punches, the main target being the head (a blow to the head was more easily scored by the judges than one to the body), with no importance set on the power of the blow. In this way the sport became less aggressive. Immediately after the insertion of this new rule, comparing competition of the same length and with the same rules (apart from the scoring system)
the rate of KO significantly decreased. However, the rate of bouts ended before time limits (ie, the sum of RSC, RSCH and KO) did not change. One can hypothesise that, with the new scoring system, it was easier to record an RSC/RSCH decision. However, there is the possibility that the referees were instructed to be more cautious and to stop the contests more quickly with the main purpose to safeguard athletes' health. In those years, following some physiological reports suggesting a relatively high fatigue with the 3×3 formula,24 25 AIBA decided to change the bout length to five rounds of 2 min each (from 1997 to 1999) and, then, to four rounds of 2 min (from 1999 to 2009). With the 5×2 formula, another significant reduction in KO rate was observed remaining more or less at these values until the present day. With the 4×2 formula, a significant reduction in RSC and RSCH rate, together with a reduced rate of matches ended before time limits was observed and it was increasingly evident after the introduction of the new rule of outclassed in 2000. This rule was adopted to safeguard athletes with evidently lower boxing skills in respect to their opponent. Boxing bouts were less spectacular and several competitions in a single tournament (mean value 15.5%) could end by RSCO. For this reason, this rule was revoked in 2009 and, at the same time, AIBA decided to go back to the old 3×3 formula. No increase in the rate of KO, RSC, RSCH and their sum was observed. One can speculate that other factors played a role in this decade so rich in rule changes, factors certainly influenced by AIBAs’ will to protect boxers’ health. For example, great steps forward have been made in materials selection, with current use of safer energy-dissipating gloves and head guards. Also careful system of training for ringside officials (referees, judges, doctors, etc) is actively running at international level and in most national federations in order to guarantee the highest level of safety inside and around the ring. Recently new AIBA’s rules to make boxing more spectacular have been adopted with other rule changes to follow from 2013, AIBA will start organising professional contests (AIBA Professional Boxing), allowing amateur boxers to compete in this form of professional boxing while still allowing them to return to take part to the Olympic Games. In professional boxing health risks are greater, as the athletes compete without head guards, for greater number of rounds (from 4 to 12) of 3 min each. Hand bandaging will be similar to current professional practice which gives the fist a much firmer covering.

In the last 59 years, improvements in health challenging verdicts recorded have been achieved by changes in the rules of boxing. It is of concern that the recent rule changes will be a backward step in athletes’ health safety. Continued medical surveillance is important to ensure that new rule changes do not result in poor medical outcomes for the boxers. A neutral structure as a specifically designed medical commission inside the AIBA or the IOC could take care of this epidemiological monitoring.

**Study limitations**

This is the first study to make a comprehensive analysis of amateur boxing rules’ changes over a six-decade period, trying...
to assess their influences on verdicts of possible medical interest. For the long-time interval evaluated, our analysis could not take into account some factors that surely influenced the results. We tried to split the entire time period in several subperiods characterised by the change of a single rule, so to extrapolate the real effect of that single rule. At times, however, this was not possible. In 1984, for example, following some severe eye injuries, the boxing glove shape was changed, adopting the so-called thumb-less gloves, with the thumb attached to/hidden by the hand to avoid entering the orbit.

Gloves’ weight changed: until 1984, boxers used 8 ounce gloves; in the following decade, lighter boxers (up to 67 kg) wore 8 ounce gloves, with the heavier athletes adopting 10 ounce gloves; in 1994 all weights used 10 ounce gloves. In the same time period several other rules were changed (mandatory head guards in 1984, computerised scoring system in 1992, 5×2 formula in 1997) and so, the result could have been affected by other confounding factors. We were not able to evaluate other issues that have influenced the rate of results over the time, as continuous advances in materials technology have occurred, with gloves and head guards more energy dissipating than those used even a decade before.

Another issue that could have affected our results is that until 1970 the technical KO decision was adopted in the same circumstances as RSC and RSCH. As, in the following years, the majority of the matches stopped before the time limit ended with an RSC decision (3.7-fold the RSCH rate), we decided to include technical KO verdicts in the RSC group for statistical analysis. In this way, from 1952 to 1970, we could have lost some decisions caused by head blows, but we used the sum of RSC, RSCH and KO decisions as a comprehensive marker of verdicts of medical interest.

CONCLUSION
Several changes have occurred in the rules of amateur boxing in the last 59 years and modern Olympic boxing is a quite different sport from that observed in the early 1950s. Looking at the rate of results of medical interest, a clear and significant reduction of health challenging results can be observed. There is no doubt that modern amateur boxing is a safer discipline than observed some decades ago.

From 2013, in International boxing, the head guards will be removed and computer scoring will be replaced with the old manual system.

It is of paramount importance to continue the surveillance of the trend in results of medical interest so that the international governing body can intervene immediately in case of any increase in poor medical outcomes.

What are the new findings?

▸ Rules’ changes in Olympic boxing clearly influenced results of medical interests in the last six decades.
▸ After mandatory head guard rule, a significant reduction of bouts ended due to medical decision (injuries) was observed.
▸ With the come back to the old 3×3 bout formula length (2009), no changes were observed in results of medical interest.

How might it impact on clinical practice in the near future

▸ New rules’ changes in international boxing will be inserted in 2013. In particular, head guards will be removed and computer scoring will be replaced with the old manual system.
▸ A strict surveillance of the trend in results of medical interest is fundamental to intervene immediately in the case of increase in poor medical outcomes.

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