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Variation in physical development in schoolboy rugby players - can maturity testing reduce mismatch?

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Variation in physical development in schoolboy rugby players - can maturity testing reduce mismatch?

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ABSTRACT

Objectives: The aim of this study was to obtain normative data for physical characteristics of current day schoolboy rugby players, a secondary aim was to assess the efficacy of an objective measure of physical maturity, the use of which has been associated with reduced injury rates.

Design: Cross sectional cohort study

Setting: Three Scottish schools and various 'regional assessment centres' organised by the Scottish Rugby Union

Participants: 382 schoolboys (across the 3 schools) aged between 12-18 years, and 472 schoolboys aged 15 assessed at the regional centres

Outcome measures: height, weight and grip strength

Results: Values of height weight and grip strength in this cohort were found substantially to exceed previous figures regarded as physically mature. When the same test for maturity was applied to the second cohort of 472 fifteen year old boys, 97.2% were deemed physically mature. Applying new parameters based on the mean data of 17 year old players resulted in 7.7% achieving maturity criteria.

Conclusion: Large morphological variation was observed in schoolboy rugby players of the same age. Previous parameters of physical maturity were not suitable to assess current schoolboys. New criteria were found to be better at differentiating 15 year old players as suitable to play senior schools rugby.

Article focus

The primary aim of this study was to obtain normative data for physical characteristics of current day schoolboy rugby players.

A secondary aim was to assess the efficacy of an objective measure of physical maturity, the use of which has been associated with reduced injury rates.

Key messages

Large morphological variation was observed in schoolboy rugby players of the same chronological age.

Previous parameters of physical maturity were not suitable to assess current schoolboys.

New criteria were found to be better at differentiating 15 year old players as suitable to play senior schools rugby.

Strengths and limitations

The screening method proposed is hypothetical without specific injury data to support its efficacy. It is however based on current population data of schoolboy rugby players and applies established concepts. Confirmation of the benefits of this system is only possible if robust mechanisms for recording injuries are implemented, which they should be as matter of major priority.

INTRODUCTION

Since the advent of professionalism in 1995, injury rates have been seen to increase in senior rugby [1] and although unproven, the same is suspected in schoolboy rugby. In 2006, Allan[2] reported an unprecedented increase in the incidence of catastrophic spinal injuries amongst teenage rugby players admitted to the Queen Elizabeth National Spinal Injuries Unit in Glasgow. Mismatch between opponents was highlighted as a possible contributory factor in these injuries.

The avoidance of mismatch is traditionally addressed by playing schoolboys in their year groups; however year groups combine at 16 to compete in senior (U18) schools rugby. In contrast to the other home nations, Scottish boys aged 15 are regularly involved in senior school rugby, in part due to the relatively small playing population and in part due to the tradition of leaving senior school at an earlier age as a consequence of the examination system.

It is well recognised that within any selected year group a wide spectrum of physical maturity exists[3] and this is likely to be at its maximum between the ages of 13 and 15 during which peak growth velocity usually occurs. In some American states a maturity assessment is used as pre-participation screening for some collision sports[4-6], and there is some evidence to suggest that matching athletes for sexual maturity is associated with a reduced injury rate[7]. Previous studies have correlated specified height and grip strength values with the attainment of physical maturity as defined by the Tanner scale[7-9]. A similar maturity assessment was introduced by the Scottish Rugby Union in the hope that, by differentiating 15 year old players by physical maturity, the risk of mismatch in this age group may be reduced.

The aim of this study was to obtain normative data for physical characteristics of current day schoolboy rugby players, a secondary aim was to assess the efficacy of an objective measure of physical maturity, the use of which has been associated with reduced injury rates.

MATREIALS AND METHODS

At the beginning of the 2009-10 season, the Scottish Rugby Union (SRU) established maturity assessment centres throughout Scotland for all 15 year olds wishing to play senior school rugby in positions other than the front row. This was introduced as part of a programme to improve safety in the game (*"Are you ready to play rugby"*) and

had been recommended by a subgroup of the Scottish Committee on Orthopaedics and Trauma (SCOT).

Testing was performed by trained medical personnel using hand held dynamometers (Jamar, Asimow Engineering Co, Los Angeles), calibrated following the manufacturer's recommendation; height and weight were measured using standard equipment. To be regarded as mature, and therefore able to play in the U-18 age group, players had to fulfil the following physical conditions[10]: height >165cm, and grip strength > 25kg.

In the second part of this study a cohort of 382 rugby-playing boys age 12 to 18 years were assessed at three Scottish rugby-playing secondary schools between December 2009 and October 2010. Height, weight, and grip strength were measured by trained personnel using the same standardised protocol. Each pupil was asked about any injury which occurred during a competitive game or during training over the preceding 12 months. An injury was defined as "any incident requiring medical advice or attention"[11]. Ethical approval was obtained from the Fife and Forth Valley Ethics Committee to undertake this part of the study. Supervision of the study was by members of the SCOT subgroup.

Data were analysed using SPSS (version 14, IBM, Chicago, USA) and manually assessed for normality. Independent samples t-tests were employed to assess differences between age grades for all variables. Statistical significance was accepted as $p<0.05$.

RESULTS

472 boys aged 15 years presented to the SRU for maturity testing. Their mean height was 1.77m (range 1.56-1.99m), mean weight 74.44kgs (range 46.00-127.05kg) and mean grip strength 44.15kgs (range 20.5-80.0kg). Using the criteria established from previous studies as an indication of physical maturity (height >165cms, grip strength > 25kg), 97.2% were deemed physically mature and thus eligible to play in the U18 age group.

382 schoolboy rugby players were assessed in the cohort study. The mean height, weight and grip strength are displayed in Table 1. As expected, the measurements increased with age. There was a statistical difference in height, weight and grip

strength year on year up to the age of 15 ($p<0.001$). Above the age of 15, year on year differences in weight and grip strength remained significant ($p<0.05$), but differences in height did not. The range of these physical parameters that exists within and between year groups is apparent in table 1 which demonstrates the potential for mismatch.

Table 1 – mean (+/-SD) physical parameters by age grade

Age	12	13	14	15	16	17	18
Height	155 +/- 7.6	163 +/- 7.8	170 +/- 7.5	175 +/- 7.0	179 +/- 7.5	180 +/- 6.2	182 +/- 8.1
Weight	48 +/- 9.2	54 +/- 10.8	61 +/- 9.8	68 +/- 11.4	72 +/- 10.2	76 +/- 12.8	84 +/- 14.9
Grip Strength	23 +/- 3.9	27 +/- 5.0	33 +/- 8.1	38 +/- 6.9	42 +/- 8.1	43 +/- 8.1	46 +/- 6.9

The incidence of injury in each age group is illustrated in Figure 1. Overall, there were 118 injuries sustained in 104 boys. Boys aged 15 years had the highest (40%) incidence of self-reported injury. As is evident in Table 2 upper limb injuries (42%) were the most prevalent site of injury in all age groups except 16 year olds in whom concussion occurred more frequently. Of the 15 boys who sustained concussions (23 injuries), 4 had sustained at least 2 separate injuries (range 2-4). Fractures constituted 31% of the injuries. There were no significant differences in injury incidence between schools.

Table 2 – injury rates per age grade

Age (years)	12	13	14	15	16	17	18
Number of players	54	66	63	65	55	62	16
Total injuries	8 (14.8)	15 (22.7)	18 (28.6)	26 (40)	15 (27.3)	17 (27.4)	5 (31.3)
Body Region							
Head / neck	2 (25)	1 (5.9)	3 (15.8)	6 (20.7)	1 (4.8)	2 (11.1)	1 (16.7)
Upper limb	4 (50)	9 (52.9)	9 (47.4)	11 (37.9)	3 (14.3)	11 (61.1)	2 (33.3)
Lower limb	2 (25)	2 (11.8)	5 (26.3)	6 (20.7)	5 (23.8)	1 (22.2)	1 (16.7)
Torso	0 (0)	0 (0)	2 (10.5)	2 (6.9)	1 (4.8)	1 (22.2)	2 (33.3)
Concussion	0	5	0	4	11	3	0

Total injuries expressed as n (% of players per age grade), injuries by body region expressed as n (% of total injuries)

As the median age of boys playing senior school rugby was 17 years, we assessed how many 15 year olds would meet the mean height, weight and grip strength of the

17 year age group (180cm height, 76kg weight and 43kg grip strength). The numbers meeting each of these criteria, and various combinations of the criteria, are shown in Table 3. Only 7.7% of the 15 year olds had the mean grip strength and weight of a 17 year old whilst including height as a requirement (the one parameter which did not continue to increase with age) reduced this figure to 6.2%.

Table 3 - Consequences of testing 15 yr olds against mean 17 yr old parameters (Height 180cm, weight 76kg, grip strength 43kg)

15 year mean	Above 17 yr old mean (n)	Below 17 yr old mean (n)	% Meeting requirement
Grip Strength + Height + Weight	4	61	6.20%
Grip Strength + Height	9	56	13.80%
Grip Strength + Weight	5	60	7.70%

The effect of applying thresholds for grip strength according to historical values (A) and those based on the values of a 17 year old (B) are displayed in Figure 2 with the resultant narrowing of range and potential reduction in mismatch that a 15 year old might encounter when playing under the new regulations.

DISCUSSION

The popularity of rugby as a sport for teenagers is threatened by concerns about the potential for serious injury[12,13]. Since the advent of professionalism in 1995, the game has become far more physical[14], and injuries in elite players are commonplace. The reported incidence of injury in youth rugby varies between countries, from 7:1000 player hours in South Africa, to 27.5:1000 player hours in New Zealand[15-17]. The difference in incidence is probably due to inconsistency in the recording of injuries, as well as lack of standardisation of injury definition. The incidence of injury has been shown to increase with age and physical maturity[18-21]. Our results for 15 year olds differ from these findings and showed a worrying increase in injury rate which would have been associated with a greater degree of physical mismatch in these players. If immature individuals play against more mature opponents with a greater muscle mass, a mismatch occurs potentially placing the less mature individual at a greater risk of injury. This was the reasoning behind incorporating maturity testing with the

"*Are you ready to play rugby*" programme introduced by the SRU in response to the rising incidence of serious spinal injuries in schoolboy rugby in Scotland.

During puberty there is an increase in body weight, principally due to muscle mass, which can be quantified by measuring grip strength. This is the principle on which our initial testing was based as suggested by other studies[10]. We focussed on 15 year olds as this age represents the watershed between junior and senior school rugby with some individuals playing at either or both levels. In addition it is during this period that major variation in physical maturity can exist.

The SRU Group results showed that height and grip strength failed to discriminate between a large cohort of 15 year old rugby players with almost all (97.2%) deemed as mature. This could be explained by suggesting that this study population was a more athletic group to that on which the parameters were based, namely youths in a juvenile correctional facility in Washington State [10]. However when compared with normative data for American adolescents in a previous study[22], the mean grip strengths for adolescent boys were almost identical to those measured in our series. The group tested by the SRU, however, were not comparable to previous normative data and represent a subset of aspiring athletes who were likely to be stronger and bigger than average for their year group. The range of values for height (1.56-1.99m), weight (46-127kg) and grip strength (21-80kg) recorded in this group of 15 year old boys is remarkable and demonstrates the variability in physical development irrespective of age.

Limited normative data exist on the physical attributes of adolescent rugby players and it was felt that this was fundamental to distinguishing between different players of the same age. Whilst weight and grip strength were observed to increase incrementally with age, height levelled off over 16 years. Height was previously recognised[23] as an important determinant of physical maturity with the period of peak growth around the "growth spurt" associated with an increased risk of injury. Peak height velocity occurs at a median age of 14 years in North American boys with the 95% confidence interval extending from 11.5 to 15.5 years[24]. In the light of this information it is not surprising that height is less likely to be a discriminator when the 15 year age group, at the upper limit of the growth spurt, is being assessed. From the normative data obtained it seemed more logical to compare the height, weight and grip strength of 15 year olds with the means of those age groups they would encounter if they played in senior school rugby. As 17 is the median age of senior

school rugby (16 -18 year group) the mean values of a 17 year old were chosen as threshold values which a 15 year old should achieve if he were to enjoy a degree of physical compatibility with his peers, hopefully reducing his risk of injury.

Table 3 demonstrated the effect of applying the mean values of the 17 year old boys in the same schools to the 15 year olds. When the different combinations of height, weight and grip strength were assessed, height proved to be the least discriminatory, as predicted. It has been recorded[10] that there is a group of taller boys who, whilst regarded as pubertally mature, do not possess the muscular strength of peers of similar height. It was therefore decided that grip strength and weight should be selected as the key parameters for testing. Using these parameters alone, 7.7% of 15 year olds in this cohort achieved the mean weight and grip strength of a 17 year old.

Whilst mismatch is recognised as an issue internationally, maturity testing is not universally practised in the major rugby playing countries. In New Zealand both age and weight are taken into account in youth rugby. Players who are significantly heavier than their peers may play at a more senior grade and underweight individuals may play down an age grade, although variation does exist between different districts. South African youth rugby is banded according to age, with players only able to play within a certain age group if their age falls within two years of that group. The Boksmart[25] rugby safety initiative was launched by the South African Rugby Union in 2009 to combat a comparatively high rate of catastrophic injuries, both in youth and senior rugby. It followed a similar programme, “Rugby smart”, in New Zealand[26] commenced in 2001 which has been shown to reduce the incidence of spinal injuries[27]. Boksmart includes comparison of individuals with normative data for age groups including body mass, fitness tests and some basic strength tests. Guidelines for players wishing to play out with their age group are well defined, requiring full rugby-specific assessments by qualified sports practitioners, letters from conditioning coaches, team doctors and coaches, confirming the suitability of the player. A similar approach exists in Australia with streaming according to age group up to U19 level, and players being unable to compete more than two years above their respective age group[28]. Those who wish to play up beyond the two-year window require their coach to fill out an exemption form addressing issues such as level of experience, playing position, use of strength training, and perceived level of maturity. In none of these countries do any objective criteria exist for physical testing.

Currently the SRU have adopted the condition that any 15 year old wishing to play in the U18 age group, in a position other than the front row, has to achieve the mean weight and grip strength of the 17 year old age group. Specified U16 age group rugby exists in some countries and the delay this imparts on the progress of 15 year olds into senior school rugby is logical, particularly as this may coincide with a time in their physical development where there is greatest variation in physical maturity. The physical variation we have observed within the same age groups however would suggest that additional assessment of physical development is advisable and this was the conclusion of a study on soccer injuries and their relation to maturity[29].

To date our focus has been on the 15 year age group. With further data collection it may be that criteria could be identified for all age bands, with players of similar physical development playing together as they mature at differing rates. Potentially this could identify more developed individuals, such as some 15 year olds observed in the SRU group, who should play in older age groups thus reducing the risk of injury to their age peers, or immature individuals who should play in younger age groups, reducing their own risk of injury.

In the absence of robust injury data, but confronted with an upsurge in serious neck injury in Scotland, it was felt that the introduction of maturity assessment in schoolboy rugby was a valuable adjunct to other measures that have been taken to increase safety. To date since the inception of these measures, no schoolboy rugby player with a serious neck injury has been admitted to the National Spinal Injuries Unit in Glasgow. It is accepted, however, that the screening method we are proposing is hypothetical without any injury data to support its efficacy. It is however based on current population data involving schoolboy rugby players, applying concepts established in American schools contact sports, based on the only literature available on this subject.

Reducing the risk of injury in contact sports should be a universal aim, and it will only be achieved once we know accurately the size and severity of the problem. Previous authors have expressed concerns regarding the wide variation in shape and size of same-aged schoolboys. We would suggest that inclusion of indicators of maturity and physical development within the injury surveillance is important. In conclusion we believe maturity testing has reduced physical mismatch in schoolboy rugby players. To confirm this assertion it is essential that rugby unions put in place robust mechanisms for recording injuries as matter of major priority.

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COMPETING INTERESTS: None

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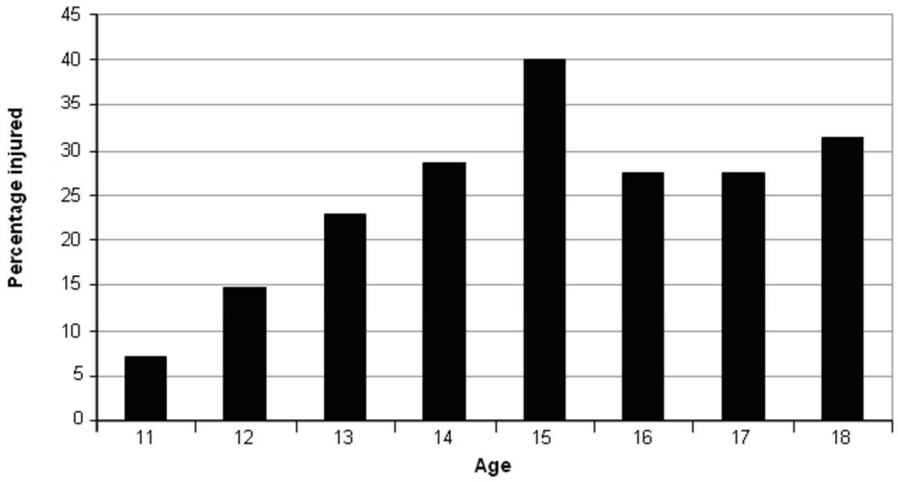
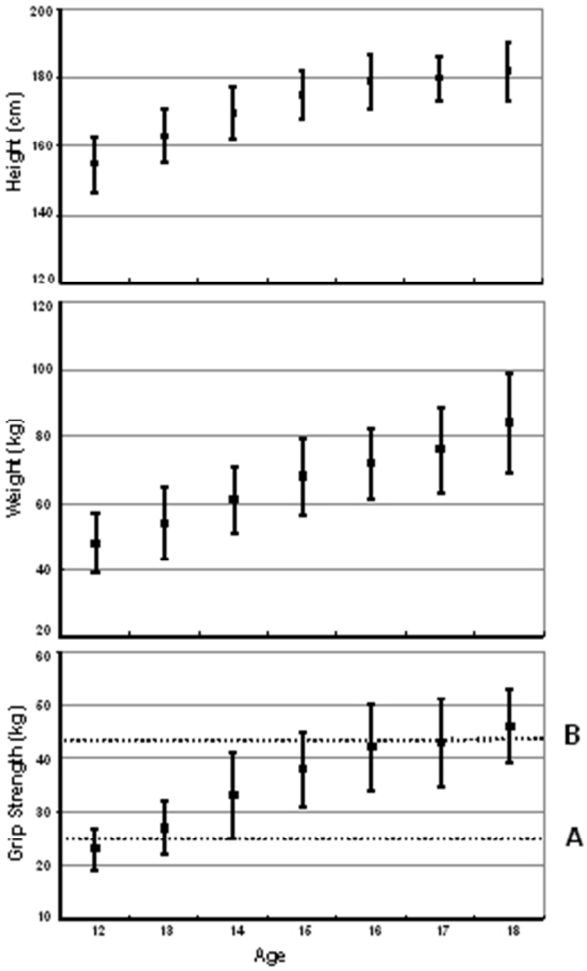


Age vs Injury Incidence



Changes in physical parameters by year group showing mean and range of values. (A previous threshold grip strength of 25kg, B current threshold grip strength of 43kg)
91x128mm (96 x 96 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3,4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3,4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	3,4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3,4
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	3
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	4
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	4
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	4,5
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	6, 7, 8, 9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6, 7, 8, 9
Generalisability	21	Discuss the generalisability (external validity) of the study results	6. 7. 8, 9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Word Count: 2880

ABSTRACT

Objectives: This study set out to pursue means of reducing mismatch in schoolboy rugby players. The primary objective was to determine whether application of previously reported thresholds of height and grip strength could be used to distinguish those 15 year old boys appropriate to play under-18 school rugby from their peers. A secondary objective was to obtain normative data for height, weight and grip strength and to assess the variation within that data of current schoolboy rugby players.

Design: Cross sectional cohort study

Setting: Three Scottish schools and 'Regional Assessment Centres' organised by the Scottish Rugby Union

Participants: 472 rugby playing youths aged 15 (Regional Assessment Centres), 382 schoolboys aged between 12-18 years (3 schools),

Outcome measures: Height, weight and grip strength

Results:
97% of 15 year olds achieved the height and grip strength thresholds based on previous reported values. Larger mean values and wide variation of height, weight and grip strength were recorded in the schoolboy cohort. However, using the mean values of the cohort of 17 year olds as a new threshold, only 7.7% of 15 year olds would pass these thresholds.

Conclusion: Large morphological variation was observed in schoolboy rugby players of the same age. Physical maturity tests described in earlier literature as pre-participation screening for contact sports were not applicable to current day 15 year old rugby players. New criteria were measured and found to be better at identifying those 15 year old players who had sufficient physical development to play senior school rugby.

Article focus

Potential for physical mismatch between schoolboy rugby players and assessment of established maturity testing methods to try to reduce this mismatch, and modifications based on new population data.

Key messages

Large morphological variation was observed in schoolboy rugby players of the same age.

Previously reported parameters of physical maturity were not suitable to assess the current schoolboy rugby playing population.

New criteria, based on current players, were found to better differentiate 15 year old players as to their suitability to play senior school rugby, with the aim of reducing physical mismatch.

Strengths and limitations

Strengths:
1. Evidence that current screening parameters are inadequately sensitive.
2. Current population data collected to describe cohorts of schoolboy rugby players.
3. Application of current data allows better assessment of physical maturity to inform the decision of whether an individual could play senior school rugby.

Limitations:
There is an urgent need to establish a robust system for recording injuries in order to substantiate the screening system.

INTRODUCTION

Since the advent of professionalism in 1995, injury rates in Rugby Union have increased in the adult game[1, 2] and although unproven, the same is suspected in schoolboy rugby[3, 4]. Serious neck and spinal injuries are thought to be rare in youth rugby[5]. In 2010, however, Allan reported an unprecedented increase in the incidence of catastrophic spinal injuries amongst teenage rugby players admitted to the Queen Elizabeth National Spinal Injuries Unit in Glasgow[6], disproportionate to the school-age playing population when compared with data for the other home nations[7]. Physical mismatch between players was highlighted as a possible contributory factor in these injuries.

The avoidance of mismatch is traditionally addressed by playing schoolboys in their year groups; however year groups combine at 16 to compete in senior (Under-18) school rugby. In contrast to the other home nations, Scottish schoolboys aged 15 are regularly involved in senior school rugby, in part due to the relatively small playing population and also due to the tradition of leaving senior school at an earlier age.

It is well recognised that within any selected year group a wide spectrum of physical maturity exists[8] and there is evidence that this is at its maximum between the ages of 13 and 15 years, during which peak growth velocity usually occurs. In some American states a maturity assessment is used as pre-participation screening for some collision sports[9-11], and there is some evidence to suggest that matching athletes for physical maturity is associated with a reduced injury rate[12]. Previous studies have correlated specified height and grip strength values with the attainment of physical maturity as defined by the Tanner scale[12-14]. A similar maturity assessment was introduced by the Scottish Rugby Union (SRU) in the hope that, by differentiating 15 year old players by physical maturity, the risk of mismatch in this age group may be reduced.

The aim of this study was to determine whether the application of previously reported threshold measurements of height and grip strength could be used to distinguish those 15 year olds who might safely play senior (Under-18) school rugby. A secondary objective was to obtain normative data for physical characteristics (height, weight and grip strength) and to assess the variation within that data of current day schoolboy rugby players to investigate whether it might give a more sensitive assessment of physical maturity.

MATERIALS AND METHODS

At the beginning of the 2009-10 season the Scottish Rugby Union (SRU) ruled that no 15 year old should play in the front row in senior school rugby. Any 15 year old wishing to play senior school rugby in an alternative position was required to undergo a maturity assessment (based on previously reported values)[15]. This was introduced as part of an intervention to improve safety in the game ("*Are you ready to play rugby*") and had been recommended by a subgroup of the Scottish Committee for Orthopaedics and Trauma (SCOT) in response to the increasing number of serious neck injuries observed in schoolboy rugby in Scotland.

An initial cohort of boys aged 15 years who wished to play senior school rugby was assessed by trained medical personnel, at several SRU-organised Regional Assessment Centres across Scotland. A specific testing protocol was followed for grip strength, height and weight. Grip strength was assessed with hand-held dynamometers (Jamar, Asimow Engineering Co, Los Angeles), calibrated as per the manufacturer's recommendations. Testing was undertaken as recommended by the American Association of Hand Surgeons with the subjects seated, the elbow flexed at 90 degrees, and the wrist in neutral. After an initial trial, three attempts were made and the mean calculated. Standardised verbal encouragement was given during the test; the boys were blinded to the values achieved until the test had been completed. Both hands

were tested and the greater mean value used for analysis. Height and weight were measured using a Leicester Height Measure and Seca 761 Approved Medical Mechanical Floor Scales (Class III) respectively. To be regarded as physically mature, and therefore able to play in the under-18 age group, players had to fulfil the following physical conditions: height >165cm, and grip strength > 25kg[15].

In the second part of this study a cohort of 382 rugby-playing boys aged 12 to 18 years were assessed at three Scottish rugby-playing secondary schools between December 2009 and October 2010. Height, weight, and grip strength were measured by trained personnel using the same standardised protocol and equipment as in the initial cohort. Ethical approval was obtained from the Fife and Forth Valley Ethics Committee (REC No: 09/S501/62) to undertake this part of the study. Individual consent was obtained from the boys who participated and countersigned by their parents where appropriate. Supervision of the study was by members of the SCOT subgroup.

Data analysis

Data were analysed using SPSS (version 14, IBM, Chicago, USA). Data were manually assessed for normality with histograms. Descriptive data are reported as means with standard deviations (SD) as a measure of dispersion. Differences between age grades were assessed with one way analysis of variance (ANOVA, General Linear Model). A Bonferroni correction was applied to reduce the chance of a type 1 error associated with multiple testing. Effect sizes are reported with the Eta^2 statistic. Post-hoc tests were performed with Tukey's HSD test to assess individual comparisons. Statistical significance was accepted as $p<0.05$.

RESULTS

472 boys aged 15 years presented to the SRU-arranged Regional Assessment Centres. Their mean height was 177 cm [SD 7 cm, range 156-199cm], mean weight 74.4 kg [SD 13.1 kg, range 46.0-127.1 kg] and mean grip strength 44.2 kg [SD 7.7 kg, range 20.5-80.0 kg]. Using the criteria established from previous studies as an indication of physical maturity (height >165cms, grip strength > 25kg), 97.2% were deemed physically mature and thus eligible to play in the under 18 age group.

382 schoolboy rugby players aged 12-18 years were similarly assessed in the second cohort study at the three schools. Mean height, weight and grip strength generally increased with age, reflecting growth (Table 1 and Figure 1).

Table 1 – physical parameters by age grade, mean (SD)

Age	12	13	14	15	16	17	18
Participants (n)	54	66	63	65	55	62	17
Height (cm)	155 (7.6)	163 (7.8)	170 (7.5)	175 (7.0)	179 (7.5)	180 (6.2)	182 (8.1)
Weight (kg)	48 (9.2)	54 (10.8)	61 (9.8)	68 (11.4)	72 (10.2)	76 (12.8)	84 (14.9)
Grip Strength (kg)	23 (3.9)	27 (5.0)	33 (8.1)	38 (6.9)	42 (8.1)	43 (8.1)	46 (6.9)

Variation in all physical parameters (height, weight and grip strength) was determined by age group (ANOVA,). Modest to large effect sizes were observed for each parameter (Table 2).

Table 2 – Effect of age on variance in assessed physical parameters (ANOVA)

	F (6, 382)	significance	η²
Height	92.27	p= <0.000	0.597
Weight	58.14	p= <0.000	0.483
Grip Strength	73.33	p= <0.000	0.541

Post hoc testing (Tukey HSD test) demonstrated significant differences between each variable in every age group up to the age of 15 years. No significant differences were observed between the 16, 17 and 18 years age groups for height or grip strength, nor between the 15, 16 17 and 18 years age brackets for weight (Table 3).

Table 3 – Inter age group comparisons (mean difference [95% CI])

Age	Height	Weight	Grip Strength
12-13	8.18 [4.21, 12.15], p=0.000	6.05 [0.07, 12.03], p=0.045	3.85 [0.10, 7.60], p=0.039
13-14	6.55 [2.74, 10.36], p=0.000	7.37 [1.63, 13.10], p=0.003	6.23 [2.63, 9.82], p=0.000
14-15	5.32 [1.49, 9.14], p=0.001	6.63 [0.87, 12.39], p=0.013	4.50 [0.89, 8.11], p=0.05
15-16	4.22 [0.26, 8.19], ,p=0.028	4.45 [-1.52, 10.42], p=0.292	3.82 [0.08, 7.56], ,p=0.042
16-17	0.58 [-3.43, 4.59], p=0.1	4.08 [-1.97, 10.14], p=0.417	1.59 [-2.19, 5.37], p=0.876
17-18	1.94 [-4.13, 8.01], p=0.964	7.90 [-1.26, 17,05], p=0.142	2.84 [-2.88, 8.56], p=0.763

Differences were however apparent between the 15 and 17 years age groups for height (difference in mean = 4.80, 95%CI [0.97, 8.65]), weight (difference in mean = 8.53 [2.73, 14.34]) and grip strength (difference in mean = 5.41 [1.79, 9.03]).

As the median age of boys playing senior school rugby in Scotland was 17 years, we assessed how many 15 year olds would meet the mean height, weight and grip strength of the 17 year age group: 180 cm height, 76 kg weight and 43 kg grip strength. The numbers meeting each of these criteria, and various combinations of the criteria, are shown in Table 4. Only 13.8% of the 15 year olds had the mean grip strength and height of a 17 year old, whilst including weight as an additional requirement reduced this figure to 6.2%.

Table 4 - Consequences of testing 15 year old boys (n=65) against the mean values for 17 year old boys (n=62; height 180 cm, weight 76 kg, grip strength 43 kg)

	Number above 17 year old mean	Number below 17 year old mean	% Meeting requirement
Grip Strength + Height	9	56	13.80%
Grip Strength + Weight	5	60	7.70%
Grip Strength, Height + Weight	4	61	6.20%

The effect of applying thresholds to the cohort data is highlighted in Figure 1, where the heavy dashed line reflects the mean values recorded for the 17 year old group, and the light dashed line the historical values (where appropriate). Of note is that current day 14 year olds (95% confidence interval of mean) meet the historical height requirement, and 13 year olds (95% CI of mean) meet the historical grip strength requirement.

DISCUSSION

The popularity of rugby as a sport for teenagers is threatened by concerns about the potential for serious injury[16, 17]. The professional game has become more physical, and injuries in elite players are commonplace[18, 19].

It is reasonable to suggest that where younger players compete with older age groups in contact sports they are exposed to higher contact forces which may be compounded if they are not physically matched. This was the reasoning behind incorporating physical assessments as part of the "*Are you ready to play rugby*" programme introduced by the SRU in 2009 in response to the rising incidence of serious spinal injuries in schoolboy rugby in Scotland. During puberty there is an increase in body weight, principally due to muscle mass, which can be quantified by measuring grip strength[15]. Our analysis focussed on 15 year old boys as this age represents the watershed between junior and senior school rugby with some individuals playing at either or both levels.

The results of applying previous threshold values for height and grip strength failed to discriminate between a large cohort of current day 15 year old rugby players with almost all (97.2%) deemed as physically mature. It may be that our study population was a more athletic group than that on which the published parameters were based, namely youths in a juvenile correctional facility in Washington State[15]. However our schoolboy cohort results were similar to normative data for American adolescents reported in a previous study[20]. In contrast, the cohort of 15 year olds tested in the SRU Regional Assessment Centres were not comparable to previous normative data and perhaps represent a subset of aspiring athletes likely to be stronger and bigger than average for their year group. The players tested in this group all wished to play at a more senior level, and are likely to be self selecting. Even so, and of more concern, the range of values for height (1.56-1.99 m), weight (46-127 kg) and grip strength (21-80 kg) recorded in this group of 15 year old boys is remarkable and demonstrates the substantial variability in physical development irrespective of age even within this subgroup of boys. This is supported by the wide standard deviations in both the SRU Regional Assessment Centre cohort and our schoolboy cohort samples, and also the confidence intervals surrounding the mean difference between age groups for all assessed parameters in the schoolboy study (Table 3).

Normative data on the physical attributes of adolescent rugby players in the literature is limited and it was felt that this was fundamental to distinguishing between different players of the same age. Whilst significant differences in height, weight and grip strength are evident across age groups in the schoolboy study (ANOVA, Table 2), *post hoc* testing reveals initial year on year significant differences only up until the age of 15 years. Thereafter, the trend of increasing mean values continues in weight and grip strength, but mean height increases are seen to level off over 16 years (Figure 1).

Height was previously recognised[21] as an important determinant of physical maturity with the period of peak growth around the "growth spurt" associated with an increased risk of injury. Peak height velocity occurs at a median age of 14 years in North American boys with the 95% confidence interval extending from 11.5 to 15.5 years[22]. It is then not surprising that height is less likely to be a discriminator when the 15 year age group, at the upper limit of the growth spurt, is being assessed. From the normative data obtained it seemed more logical to compare

the height, weight and grip strength of 15 year olds with the means of those age groups they would encounter if they played in senior school rugby. As 17 years is the median age of senior school rugby (16 -18 year group), the mean values for a 17 year old were chosen as threshold values which a 15 year old should achieve if he were to enjoy a degree of physical compatibility with these older players, hopefully reducing his risk of injury. Table 4 highlights the effect of applying the mean values of the 17 year old boys to the 15 year old age group. When the different combinations of height, weight and grip strength were assessed, height proved to be the least discriminatory, as predicted. It has been recorded that there is a group of taller boys who, whilst regarded as pubertally mature, do not possess the muscular strength of peers of similar height[15]. It was therefore decided that grip strength and weight should be selected as the key parameters for testing. Using these parameters alone, 7.7% of 15 year olds in this cohort achieved the mean weight and grip strength of a 17 year old.

Whilst mismatch is recognised as an issue internationally, neither maturity nor grip strength testing is routinely tested in the major rugby playing countries. In New Zealand, both age and weight are taken into account in banding for youth rugby. Players who are significantly heavier than their peers may play at a more senior grade and underweight individuals may play down an age grade, although variation does exist between different districts. South African youth rugby is banded according to age, with players only able to play within a certain age group if their age falls within two years of that group. The *BokSmart*[23] rugby safety initiative was launched by the South African Rugby Union in 2009 to combat a comparatively high rate of catastrophic injuries, both in youth and senior rugby. This was a similar programme to the *RugbySmart* initiative in New Zealand[24] which commenced in 2001 and has been shown to reduce the incidence of spinal injuries[25]. *BokSmart* includes comparison of individuals with normative data for age groups including body mass, fitness tests and some basic strength tests. Guidelines for players wishing to play out with their age group are well defined, requiring full rugby-specific assessments by qualified sports practitioners, letters from conditioning coaches, team doctors and coaches, confirming the suitability of the player. A similar approach exists in Australia with streaming according to age group up to U19 level, and players being unable to compete more than two years above their respective age group[26]. Those who wish to play up beyond the two-year window require their coach to fill out an exemption form addressing issues such as level of experience, playing position, use of strength training, and perceived level of maturity. In none of these countries do any objective criteria exist for physical testing.

Currently the SRU have adopted the condition that any 15 year old wishing to play Under-18 rugby, in a position other than the front row, has to achieve the mean weight and grip strength of 17 year old players. Front row players aged 15 years are not allowed to play in the Under-18 age group; this decision was based on reports in the literature that serious neurological damage was more common following neck injury sustained in the scrum in UK schoolboys rather than the tackle[7]. Specified under-16 age group rugby exists in some countries and the delay this imparts on the progress of 15 year olds into senior school rugby is logical, particularly as this may coincide with a time in their physical development where there is greatest variation in physical maturity. To date our focus has been on the 15 year age group. With further data collection it may be that criteria could be identified for all age bands, with players of similar physical development playing together as they mature at differing rates. Potentially this could identify more developed individuals who should play in older age groups thus reducing the risk of injury to their age peers, or immature individuals who should play in younger age groups, reducing their own risk of injury.

In the absence of robust injury data, but confronted with an upsurge in serious neck injury in Scotland, it was felt that the introduction of maturity assessment in schoolboy rugby was a valuable adjunct to other measures that have been taken to increase safety. To date since the inception of these measures, no schoolboy rugby player with a serious neck injury has been

admitted to the National Spinal Injuries Unit in Glasgow. It is accepted, however, that the screening method we are proposing is hypothetical without any injury data to support its efficacy. It is however based on current population data involving schoolboy rugby players, applying concepts established in American schools contact sports, based on the only literature available on this subject.

In conclusion we have demonstrated that maturity testing using previously reported parameters fails to differentiate between current day 15 year old Scottish schoolboy rugby players. Matching schoolboys for weight and grip strength, introducing a safety margin based on current population data, where younger players wish to compete above their age group is more likely to be an effective method of reducing mismatch.

Reducing the risk of injury in contact sports should be a universal aim, and it will only be achieved once we know accurately the size and severity of the problem. Previous authors have expressed concerns regarding the wide variation in shape and size of same-aged schoolboys. We suggest that inclusion of indicators of physical maturity within an injury surveillance framework is important if we are to establish the risks associated with mismatch of age grade players. Until such data is available it would seem logical to try and minimise mismatch which is what we have set out to achieve with this initiative.

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FUNDING: The first cohort of testing was funded by the Scottish Rugby Union. The second cohort of schools based testing received support from the Hearts and Balls charity to purchase testing equipment.

COMPETING INTERESTS: None

FIGURE LEGEND

Figure 1 – Assessed physical parameters with cut-off thresholds

Legend: Mean values with 95% confidence intervals for (a) height, (b) weight and (c) grip strength of the 382 schoolboys assessed. The heavy dashed line represents the 17 year old mean, and allows direct comparison of the number of younger boys likely to achieve this value. The lighter dashed line reflects the previously used criteria (height and grip strength only) demonstrating the poor reflection of these previous scores on current day Scottish schoolboy rugby players

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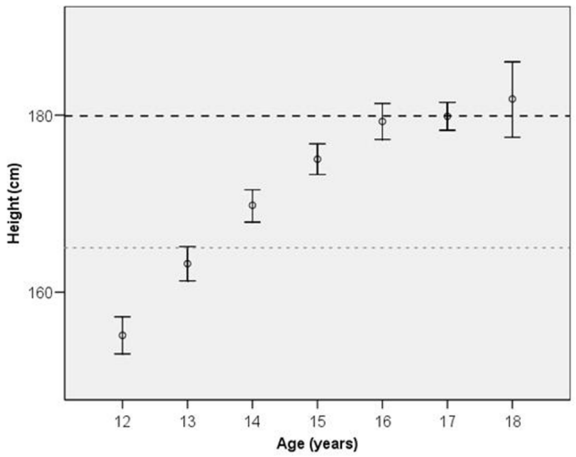

Legend: Mean values with 95% confidence intervals for (a) height, (b) weight and (c) grip strength of the 382 schoolboys assessed. The heavy dashed line represents the 17 year old mean, and allows direct comparison of the number of younger boys likely to achieve this value. The lighter dashed line reflects the previously used criteria (height and grip strength only) demonstrating the poor reflection of these previous scores on current day Scottish schoolboy rugby players
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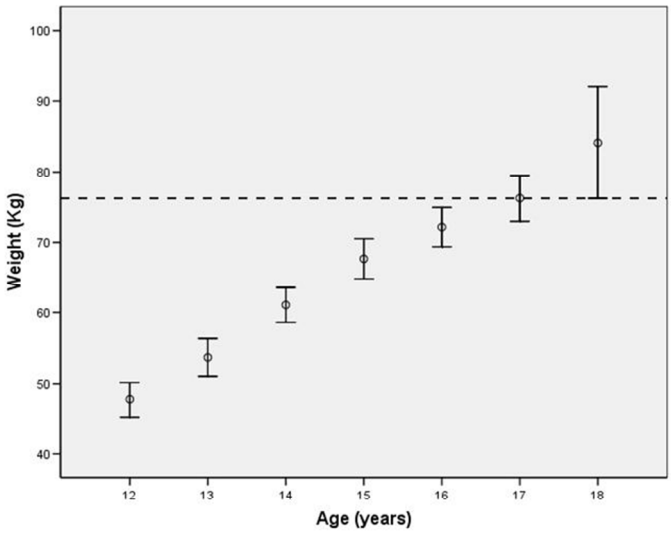

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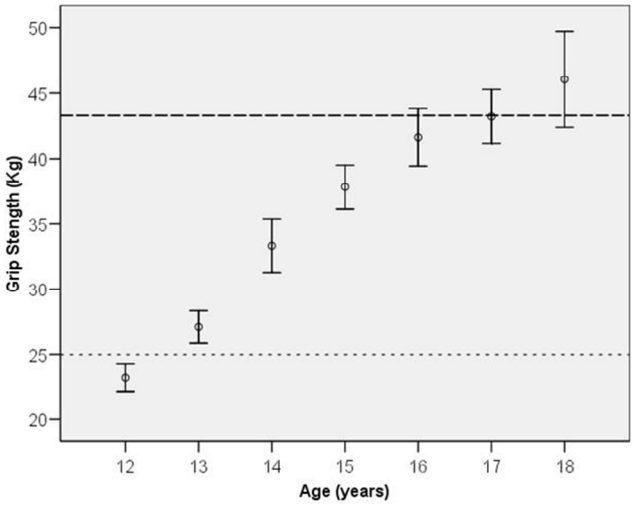

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3,4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3,4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	3,4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3,4
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	3
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	4
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	4
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	4,5
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	6, 7, 8, 9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6, 7, 8, 9
Generalisability	21	Discuss the generalisability (external validity) of the study results	6. 7. 8, 9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.