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ORIGINAL RESEARCH

ULTRASONOGRAPHIC ASSESSMENT OF NECK MUSCULAR SIZE AND RANGE OF MOTION IN RUGBY PLAYERS

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ABSTRACT

Background: World Rugby Union laws are constantly evolving towards stringent injury-prevention, particularly for contested scrums, since front row players are most at risk of cervical spine injuries. Recently, some countries have also introduced tailored training programs and minimum performance requirements for playing in the front row. Nevertheless, these approaches lack an objective assessment of each cervical muscle that would provide protective support.

Objective: Since front row players are the most at risk for cervical spine injuries due to the specific type of contact during scrums, the purpose of this study was to ascertain whether significant differences exist in neck muscle size and range of motion between front row players and players of other positions, across playing categories.

Study Design: Cross-sectional controlled laboratory study

Methods: 129 sub-elite male subjects from various first-team squads of Belgian Rugby clubs were recruited. Subjects were grouped according to age: Junior (J) < 19 years old, Senior (S) 19 to 35 years old and Veteran (V) > 35 years old; as well as playing position: Front row players (J = 10, S = 12, V = 11 subjects), (Rest of the) pack (J = 12, S = 12, V = 10), backs (J = 10, S = 11, V = 11). An age-matched control group of non-rugby players was also recruited (J = 10, S = 10, V = 10).

For each subject, the total neck circumference (NC) and the cervical range of motion (CROM) were measured. In addition, the thickness of the trapezius (T), splenius capitis (SCa), semispinalis capitis (SCb), semispinalis cervicis (SPC), sternocleidomastoid muscles (SCOM), and the total thickness of all four structures (TT), were measured using ultrasonography.

Results: In each age category, compared to controls, rugby players were found to have decreased CROM, an increase in neck circumference (NC), and increased total thickness (TT), trapezius (T), semispinalis capitis (SCb) and sternocleidomastoid muscles (SCOM) sizes. For junior players, the thickness of the semispinalis cervicis (SPC) was also increased compared to controls. The CROM was decreased in front row players compared to pack and back players for all age categories; Front row seniors also showed an increase in trapezius (T), splenius capitis (SCa), semispinalis capitis (SCb) and total thickness (TT), compared to back players.

Conclusion: In regard of the differences in cervical values found between player positions, the implementation of both range of motion and echography muscle thickness assessments could serve to create an additional measurement for all front row players, that could complement current pre-participation screening used by rugby federations by objectively monitoring muscular size and motion amplitude around the cervical spine.

Keywords: Ultrasonography, musculoskeletal ultrasound, rugby scrum, neck

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INTRODUCTION

Five percent of rugby injuries are to the cervical spine region, ranging from benign lesions such as sprains or muscular bruises, to spinal cord injuries.[1,2] Fortunately, serious injuries are becoming less frequent, due to a continuous evolution of the game's rules.[3] Nevertheless, rugby remains one of the most injury-prone sports as far as cervical injuries are concerned.[4] There is not a significant difference in types of injuries between professional players and amateurs.[5] However, the younger player categories are spared, because of appropriate scrum rules, contacts being less rough and the power of players (weight and speed) being less developed. In fact, the incidence of cervical injury was shown to increase by age category: 68% for over 21 year old players, 23% for 17-21 year olds, 3% for 15-17 year olds, and 3% for 13-15 year olds.[6]

During scrums, the front row players, positioned with arms interlocked and heads down with the rest of their pack (five other players) pushing from behind, are in direct frontal close contact with the opponent's front row and pack players who are pushing against them. Fifty-eight percent of cervical spine injuries[7,8] in rugby are sustained by front row players during scrums. Another important source of neck injuries in rugby comes in the form of facet dislocations caused by impact sustained during contacts and tackles.[9]

In world Rugby Union regulations, it is the team's responsibility to ensure that all front row players and potential front row replacements are suitably trained and equipped to deal with the demands of the position (especially scrummaging). It is not for the referee to determine whether any player is suitably trained or physically and morphologically equipped to play in the front row. Unfortunately, there are no specifications as to what comprises suitable training, nor does a standard objective assessment of the size of cervical muscles for front row players exist to determine minimum morphological readiness to playing in the front row. Researchers have shown that increased muscle strength and size reduces the risk of injuries.[10-13]

Ultrasound imaging is a relatively inexpensive, portable, non-ionizing, non-invasive and real-time diagnostic modality. Ultrasound imaging is therefore proposed as a means to complement the usual medical assessment approaches by objectively assessing each muscle in the cervical region, and describing size norms for front row players which could be correlated to cervical protective support towards injury prevention in future studies. Since front row players are the most at risk for cervical spine injuries due to the specific type of contact during scrums, the purpose of this study is to ascertain whether significant differences exist in neck muscle size and range of motion between front row players and players of other positions, across playing categories.

METHODS

Subjects

This study was conducted in accordance with the Declaration of Helsinki after approval by the Academic Ethical Committee of Brussels (B 200–2013-081) and written informed consent.

Male volunteers were recruited from Belgian first division rugby clubs so that a minimum of 10 subjects were included in each of the following nine categories:

- Junior (J) < 19 years old, divided into front row players, (rest of the) pack and backs
- Senior (S) 19 to 35 years old, divided into front row players, (rest of the) pack and backs
- Veteran (V) > 35 years old, divided into front row players, (rest of the) pack and backs

In addition, three age-matched control groups, with a minimum of 10 subjects each, were also recruited for the junior, senior and veteran age categories.

All rugby players participating in the study had no current or previous cervical or spinal pathologies and had passed a medical examination confirming no contra-indication to the practice of rugby. The controls were all people practicing sports, at least three times a week for no less than 90 min per session. They were submitted to the same medical examination, which includes no contraindications to the practice of sports and no cervical or spinal problems.

Measurements

Each subject was measured at least three hours after having finished any form of physical activity. Ultrasound measurement reliability has been previously established for neck measurements, with an intra-class correlation coefficient of 0.82 and lower limit of detectable changes around 0.8-2.1 mm, as well as no demonstrable bias between experienced assessors.[14-17] In this study, the average of three repeated measurements was taken for each parameter by the same researcher physiotherapist to further minimize measurement errors. Prior to the start of this study, the physiotherapist received additional training with a radiologist until measurement consistency was verified and accepted. A post-hoc evaluation of measurement consistency found an intra-class correlation coefficient of 0.98, demonstrating an excellent measurement consistency. This was done by measuring all five muscles' thicknesses seven times with ultrasound (as described hereafter in *Ultrasound muscle thickness measurements*), on both the left and the right side, and repositioning the subject completely every time (starting from a standing position). For each of the seven measurements, as in the study, the average of three measurements was taken, and the breakdown of all individual measurements is reported in Appendix A. The intra-class correlation coefficient, a measure of measurement consistency for continuous data, was then calculated for all 10 muscles thicknesses (five left and five right side) between the seven measures.

Cervical range of motion (CROM):

The cervical range of motion (CROM) instrument (CROM Basic, PhysioSupplies, NL) was used to assess the amplitudes (range of motion) of different cervical movements, due to its practicality, good repeatability and accuracy.[18,19] The subjects sat on a chair with a vertical backrest, both feet flat on the ground, head and back straight and detached from the backrest, looking straight forward to a fixed point (called the 'neutral position'), adapted from the literature[20] to maintain the natural spinal curves. After calibration, the CROM instrument was fixed onto the subject's head and they performed maximum active range of movements, in flexion, extension, right and left rotation, and right and left side bending of the head (inclination of the neck). The experimenter placed his hands on the subjects' shoulders to detect and correct any errors in posture or compensation.

Ultrasound muscle thickness measurements:

The thicknesses of anterior and posterior muscles of the neck, choosing the most voluminous portion on the echography plane for repeatability, were also measured bilaterally, in the same sitting position as for the CROM measurements described above, using a portable ultrasound machine (DP 6600, Mindray Bio-Medical Electronics Co, Shenzhen, China): trapezius (T), splenius capitis (SCa), semispinalis capitis (SCb), semispinalis cervicis (SPC) and sternocleidomastoid muscles (SCOM).

Measurements were performed at the cervical level C5-C6 corresponding with where the largest number of injuries occur in rugby.[9] For the posterior muscles, the subject was asked to position himself in maximum active cervical flexion. The linear probe of the ultrasound (bandwidth 5-10MHz) was placed 2 cm laterally to the C6 level as determined by palpation of the spinous process to standardize measurements with an appropriate visualization of the desired structures. After freezing the image (Figure 1), the experimenter measured the thickness of the various muscles: T, SCa, SCb and SPC. The total thickness (TT) of these four structures was also recorded. For the SCOM on both sides, the subjects were asked to take the neutral position, as described above, and measurements were taken at the C6 level to visualize the thickest portion of the SCOM (Figure 2).

Neck circumference:

The neck circumference (NC) was measured using a flexible tape, with the subject seated in the neutral position. To guarantee accurate measurements, the tape measure was placed perpendicularly to the neck under the thyroid cartilage, directly below the laryngeal prominence, taking care not to compress any structures and/or subjacent tissue.

Statistical analyses

All statistical analyses were done with GraphPad Prism[21] and the significance level set a priori at $p < 0.05$. All twelve subgroups were compared to each other for each measurement. Normal distribution tests were done using Kolmogorov-Smirnov, d'Agostino and

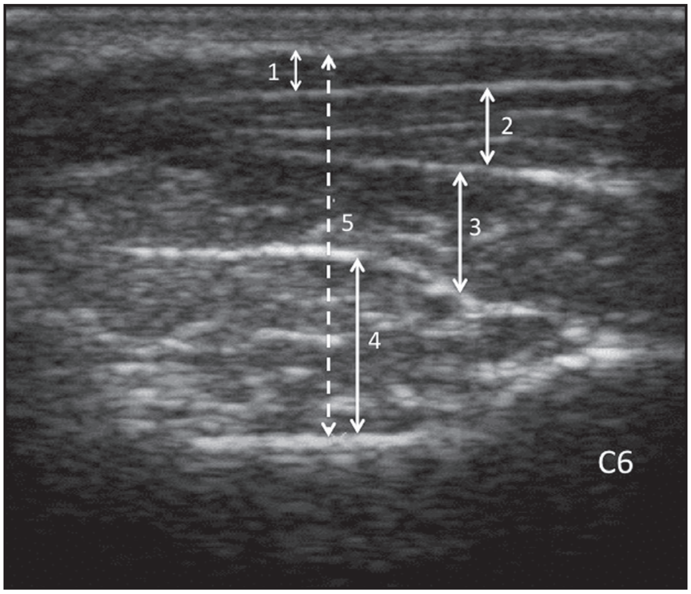

Figure 1. *Example ultrasound image for anatomical measurements: trapezius (1), splenius capitis (2), semispinalis capitis (3), semispinalis cervicis (4) and the total thickness of these four structures (5).*

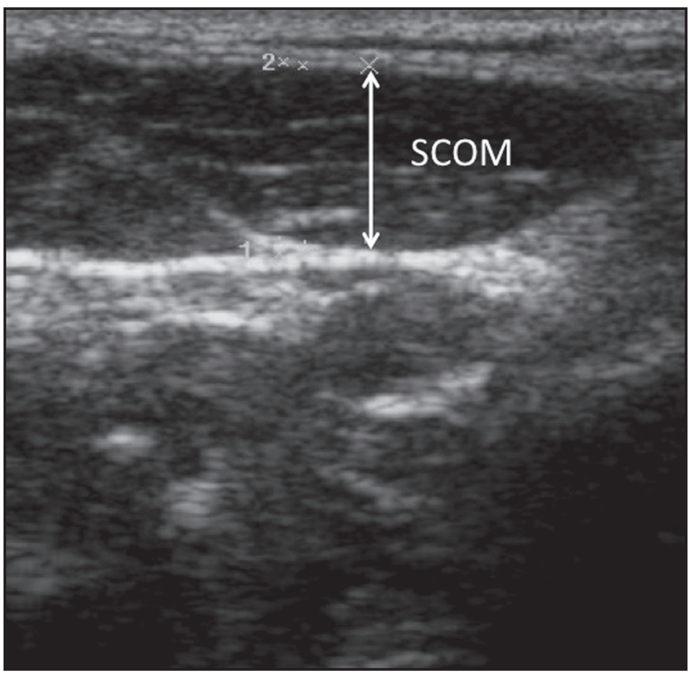

Figure 2. *Example ultrasound image for the sternocleidomastoid muscle (SCOM).*

Pearson and at least one sample was found non-normally distributed each time. Thus, Kruskal-Wallis (non-parametric) tests with Dunn's post-test were used.

RESULTS

One hundred and twenty-nine male volunteers, aged 15 to 54 were recruited for this study and subdivided by age category and player position. A control group of non-rugby players was also recruited and divided into age-matched control groups, thus creating twelve sub groups, each with 10-12 subjects (Tables 1 and 2).

Comparisons between player positions within each age category

Tables 3, 4 and 5 show the statistical comparison for each measurement (CROM, muscle sizes and NC) between players from different position categories and include the statistical comparisons between players and age-matched controls.

For *juniors*, the significant differences between players and controls included NC, flexion, left and right T, left and right TT, left and right SCOM between pack players and controls, flexion, left and right SPC thickness between backs and controls, and all measures other than left rotation, left and right and SCa thickness, between front players and controls.

For *veterans*, the significant differences between players and controls included right rotation, left and right TT between pack players and controls, NC, flexion, extension, right and left rotations, left and right T, left and right SCb, left and right TT, left and right SCOM between front players and controls, NC between front and pack players, as well as NC and flexion between front and back players.

For *seniors*, the significant differences between players and controls included NC, flexion, right rotation, left and right SCb, left and right TT, left and right SCOM, right T between front and back players, NC between front and pack players, as well as NC, extension, right rotation, left and right SCb, left and right TT, left and right SCOM, right T between front players and controls. No differences were found between pack players, back players and controls in this age category.

Comparisons between age-categories for same player positions

In addition to position comparisons, players in the same position but in different age categories were also compared for each measured quantity. All results were not significant, apart from the following four quantities:

Table 1. *Anthropomorphic measurements of recruited subjects by age group. Reported as mean ± standard deviation.*

Age group definitions	Number of subjects	Age (yrs)	Height (cm)	Weight (kg)	BMI	Weekly training time (hrs/week)
Junior (J): 15 to 18 yrs old	42	17 ± 1.19	178 ± 6.45	77 ± 15.6	24.2 ± 4.0	7 ± 2
Senior (S): 19 to 34 yrs old	45	25 ± 2.53	180 ± 5.72	85 ± 14.4	26.3 ± 4.1	6 ± 1
Veteran (V): 35 to 54 yrs old	42	44 ± 6.39	180 ± 6.49	92 ± 15.5	28.4 ± 4.5	2 ± 1

Table 2. *Number of subjects in each age category by row position for rugby players and control subjects.*

	Front (1)	Pack (2)	Back (3)	Control (C):
Junior	N=10	N=12	N=10	N=10
Senior	N=12	N=12	N=11	N=10
Veteran	N=11	N=10	N=11	N=10

Front= Front row players, Pack= 2nd and 3rd row players, Back= back players, Control= control group of non-rugby players.

Table 3. *Statistical comparisons of measured parameters for different row players within the junior (J) age category. All data are presented as means ± standard deviation.*

	Juniors				Comparisons					
	1st Row (J1)	Pack (J2)	Back (J3)	Control Group (JC)	J1 / J2	J1 / J3	J1 / JC	J2 / J3	J2 / JC	J3 / JC
Neck circumference (cm)	41.5 ± 2.9	40.0 ± 2.5	39.0 ± 2.1	36.2 ± 1.1	ns	ns	***	ns	*	ns
Flexion (°)	54 ± 7	56 ± 5	55 ± 4	72 ± 5	ns	ns	**	ns	*	*
Extension (°)	52 ± 3	59 ± 4	58 ± 8	68 ± 5	ns	ns	**	ns	ns	ns
Right Rotation (°)	60 ± 5	63 ± 5	64 ± 4	70 ± 3	ns	ns	*	ns	ns	ns
Left Rotation (°)	62 ± 6	64 ± 5	63 ± 4	71 ± 3	ns	ns	ns	ns	ns	ns
Right Side Bending(°)	35 ± 5	40 ± 3	42 ± 3	48 ± 4	ns	ns	***	ns	ns	ns
Left Side Bending (°)	37 ± 6	40 ± 4	42 ± 3	49 ± 3	ns	ns	***	ns	ns	ns
1-L Trapezius (mm)	4.30 ± 1.00	3.67 ± 0.57	3.28 ± 0.46	2.34 ± 0.31	ns	ns	***	ns	*	ns
2-L Splenius capitis (mm)	6.97 ± 1.29	6.87 ± 1.26	6.07 ± 1.45	5.12 ± 0.50	ns	ns	ns	ns	ns	ns
3-L Semispinalis capitis (mm)	11.22 ± 2.30	9.62 ± 0.97	9.20 ± 1.69	8.03 ± 0.47	ns	ns	**	ns	ns	ns
4-L Semispinalis cervicis (mm)	8.20 ± 0.82	7.52 ± 0.93	9.11 ± 1.28	5.87 ± 0.65	ns	ns	**	ns	ns	***
Total Left (mm)	30.42 ± 2.75	28.44 ± 2.87	28.24 ± 4.34	23.00 ± 1.10	ns	ns	***	ns	*	ns
5-L SCOM (mm)	14.85 ± 2.24	14.23 ± 1.50	12.48 ± 1.01	10.22 ± 1.15	ns	ns	***	ns	***	ns
1-R Trapezius (mm)	4.40 ± 1.11	3.92 ± 0.69	3.37 ± 0.35	2.40 ± 0.20	ns	ns	***	ns	***	ns
2-R Splenius capitis (mm)	6.92 ± 1.29	6.67 ± 1.26	5.96 ± 1.45	5.12 ± 0.50	ns	ns	ns	ns	ns	ns
3-R Semispinalis capitis (mm)	11.16 ± 2.03	9.76 ± 0.95	9.31 ± 1.64	8.06 ± 0.55	ns	ns	**	ns	ns	ns
4-R Semispinalis cervicis (mm)	8.34 ± 0.61	7.48 ± 1.26	9.47 ± 1.59	5.96 ± 0.61	ns	ns	**	ns	ns	***
Total right (mm)	30.59 ± 2.48	28.64 ± 2.76	28.05 ± 3.61	23.09 ± 1.04	ns	ns	***	ns	*	ns
5-R SCOM (mm)	14.80 ± 1.92	14.42 ± 1.38	12.61 ± 1.14	10.06 ± 1.16	ns	ns	***	ns	***	ns

1= front players; 2= pack players (middle); 3= backs; C= control (non-rugby players), SCOM= sternocleidomastoid muscle
*= p<0.05, **= p<0.01 and***= p<0.001, ns= no statistically significant difference

- J1/V1 neck circumference ($p < 0.001$)
- JC/VC neck circumference ($p < 0.001$)
- J1/V1 neck extension range of motion ($p < 0.01$)
- S3/V3 neck right rotation amplitude ($p < 0.05$)

DISCUSSION

The results show few differences between age-categories for the same player positions; however, there were several significant differences between players and controls, as well as between the front row players versus other players (especially back players in some age-categories.)

Table 4. *Statistical comparisons of measured parameters for different playing positions within the senior (S) age-category. All data are presented as means ± standard deviation.*

	Seniors				Comparisons					
	1st Row (S1)	Pack (S2)	Back (S3)	Control Group (SC)	S1 / S2	S1 / S3	S1 / SC	S2 / S3	S2 / SC	S3 / SC
Neck circumference (cm)	44.5 ± 1.9	41.2 ± 1.2	39.7 ± 1.6	38.0 ± 2.6	*	***	***	ns	ns	ns
Flexion (°)	49 ± 7	55 ± 4	63 ± 9	61 ± 8	ns	*	ns	ns	ns	ns
Extension (°)	49 ± 5	57 ± 5	60 ± 5	66 ± 6	ns	ns	***	ns	ns	ns
Right Rotation (°)	55 ± 4	61 ± 5	65 ± 5	66 ± 8	ns	**	**	ns	ns	ns
Left Rotation (°)	57 ± 4	63 ± 5	65 ± 9	65 ± 8	ns	ns	ns	ns	ns	ns
Right Side Bending(°)	35 ± 6	38 ± 6	41 ± 5	45 ± 9	ns	ns	ns	ns	ns	ns
Left Side Bending (°)	35 ± 6	39 ± 6	42 ± 4	44 ± 8	ns	ns	ns	ns	ns	ns
1-L Trapezius (mm)	4.13 ± 0.52	3.76 ± 0.74	3.00 ± 0.61	2.99 ± 0.93	ns	*	ns	ns	ns	ns
2-L Splenius capitis (mm)	7.77 ± 1.79	6.76 ± 1.31	5.46 ± 1.09	5.56 ± 1.58	ns	*	ns	ns	ns	ns
3-L Semispinalis capitis (mm)	12.82 ± 1.98	9.93 ± 1.33	8.75 ± 1.35	8.40 ± 1.51	ns	**	***	ns	ns	ns
4-L Semispinalis cervicis (mm)	8.82 ± 1.64	8.09 ± 1.07	7.65 ± 1.90	6.93 ± 1.51	ns	ns	ns	ns	ns	ns
Total Left (mm)	33.83 ± 2.16	29.19 ± 1.66	26.77 ± 1.63	24.8 ± 3.21	ns	**	***	ns	ns	ns
5-L SCOM (mm)	16.14 ± 1.90	13.52 ± 1.55	12.85 ± 1.24	11.7 ± 1.21	ns	ns	***	ns	ns	ns
1-R Trapezius (mm)	4.30 ± 0.41	3.71 ± 0.76	3.19 ± 0.47	3.07 ± 0.86	ns	*	*	ns	ns	ns
2-R Splenius capitis (mm)	7.99 ± 1.79	6.70 ± 1.31	5.63 ± 1.09	5.69 ± 1.58	ns	*	ns	ns	ns	ns
3-R Semispinalis capitis (mm)	12.95 ± 2.01	10.41 ± 1.25	9.00 ± 0.95	8.39 ± 1.53	ns	**	***	ns	ns	ns
4-R Semispinalis cervicis (mm)	8.61 ± 1.53	8.01 ± 1.03	7.40 ± 1.89	7.20 ± 1.35	ns	ns	ns	ns	ns	ns
Total right (mm)	34.18 ± 2.22	29.35 ± 2.00	27.14 ± 1.84	25.22 ± 2.81	ns	**	***	ns	ns	ns
5-R SCOM (mm)	17.11 ± 1.63	13.62 ± 1.55	12.66 ± 1.06	12.36 ± 1.47	ns	**	***	ns	ns	ns

1= front players; 2= pack players (middle); 3= backs; C= control (non-rugby players), SCOM= sternocleidomastoid muscle
*= p<0.05, **= p<0.01 and***= p<0.001, ns= no statistically significant difference

Table 5. *Statistical comparisons of measured parameters for different playing positions within the veteran (V) age-category. All data are presented as means ± standard deviation.*

	Veterans				Comparisons					
	1st Row (V1)	Pack (V2)	Back (V3)	Control Group (VC)	V1 / V2	V1 / V3	V1 / VC	V2/ V3	V2 / VC	V3 / VC
Neck circumference (NC) (cm)	46.7 ± 2.7	42.0 ± 2.5	41.4 ± 1.70	40.5 ± 2.80	***	***	***	ns	ns	ns
Flexion (°)	45 ± 8	52 ± 6	58 ± 6	62 ± 6	ns	*	***	ns	ns	ns
Extension (°)	39 ± 7	50 ± 6	47 ± 6	56 ± 7	ns	ns	*	ns	ns	ns
Right Rotation (°)	48 ± 8	55 ± 7	56 ± 5	65 ± 8	ns	ns	***	ns	*	ns
Left Rotation (°)	51 ± 7	55 ± 5	56 ± 6	66 ± 6	ns	ns	**	ns	ns	ns
Right Side Bending(°)	31 ± 7	34 ± 7	34 ± 6	40 ± 4	ns	ns	ns	ns	ns	ns
Left Side Bending (°)	34 ± 5	34 ± 8	38 ± 6	40 ± 4	ns	ns	ns	ns	ns	ns
1-L Trapezius (mm)	3.97 ± 0.65	3.63 ± 0.61	3.03 ± 0.49	2.53 ± 0.44	ns	ns	**	ns	ns	ns
2-L Splenius capitis (mm)	7.08 ± 1.05	6.62 ± 1.19	6.04 ± 1.09	5.20 ± 0.72	ns	ns	ns	ns	ns	ns
3-L Semispinalis capitis (mm)	11.4 ± 1.31	10.68 ± 1.37	9.18 ± 0.80	8.27 ± 0.91	ns	ns	**	ns	ns	ns
4-L Semispinalis cervicis (mm)	7.79 ± 1.19	7.74 ± 2.08	7.53 ± 1.10	6.01 ± 0.86	ns	ns	ns	ns	ns	ns
Total Left (mm)	31.15 ± 2.84	29.97 ± 2.48	27.57 ± 2.56	24.48 ± 1.30	ns	ns	**	ns	*	ns
5-L SCOM (mm)	14.62 ± 1.87	13.57 ± 2.03	11.95 ± 0.94	10.83 ± 0.43	ns	ns	***	ns	ns	ns
1-R Trapezius (mm)	3.88 ± 0.62	3.64 ± 0.76	3.06 ± 0.40	2.53 ± 0.25	ns	ns	**	ns	ns	ns
2-R Splenius capitis (mm)	6.94 ± 1.05	6.23 ± 1.19	5.83 ± 1.09	5.33 ± 0.72	ns	ns	ns	ns	ns	ns
3-R Semispinalis capitis (mm)	11.37 ± 1.30	10.75 ± 1.39	9.25 ± 1.18	8.46 ± 0.68	ns	ns	**	ns	ns	ns
4-R Semispinalis cervicis (mm)	7.84 ± 0.72	7.63 ± 1.71	7.25 ± 0.86	6.07 ± 0.97	ns	ns	ns	ns	ns	ns
Total right (mm)	31.43 ± 2.63	29.94 ± 2.15	27.42 ± 1.94	24.63 ± 1.32	ns	ns	***	ns	*	ns
5-R SCOM (mm)	14.94 ± 1.60	13.79 ± 1.91	12.36 ± 1.17	11.06 ± 0.89	ns	ns	***	ns	ns	ns

1= front players; 2= pack players (middle); 3= backs; C= control (non-rugby players), SCOM= sternocleidomastoid muscle
*= p<0.05, **= p<0.01 and***= p<0.001, ns= no statistically significant difference

Neck circumference is a global size measurement; however, ultrasonography makes it possible to measure the size of specific muscles. In particular, SCb is significantly thicker in players than in controls, and in particular in front row players, in all age-categories. This could be a result of the specific demands of rugby where the ball is always passed backwards and this sport specific movement is associated with significant trunk and neck rotations. Ultrasonography thus allows individual muscle assessment and could be used to monitor targeted strengthening, especially for front row players.

Comparisons between age-categories

There are few statistical differences for the same player positions between different age-categories. The neck circumference of veteran front row players was larger than that of front row junior players; however, this increase with age was also found in the control population. Therefore, this is most likely not related to the practice of rugby and the difference is probably due to normal aging.

The only significant differences include neck extension range of motion, which decreases in veterans compared to junior front players, as well as neck right rotation range of motions, which decreases in veterans compared to senior back players. The extension range of motion decreases with the age of the front row rugby players: there is a statistically significant difference between front row junior and veteran players. The decrease in extension range of motion is consistent with previous studies[22] but this seems to be exacerbated in rugby players since the same changes were not seen in the control group. There is evidence that exercise and training affects the flexibility of connective tissue and thus may impact the cervical range of motion.[23] This can also potentially explain the decrease in the right rotation amplitude found in back player veterans compared to seniors, as the continued practice of rugby may exacerbate any normal aging differences due to the sustained cervical strains in response to the practice of rugby.[24,25]

Comparisons between rugby players and controls

Differences in range of motion as well as muscle size were found between players and controls in all age-categories. This is not surprising as it points to specific adaptations that occur in response to the practice of rugby.

The decrease in motion amplitude found in rugby players could be related to the larger neck circumference compared to controls. This additional mass could restrict the range of movement and increase the endurance of the superficial (external) stabilizers of the vertebral column.[26] This hypothesis is supported by the fact that these observations are most pronounced in front row players. Indeed, during a scrum push, a stabilizing isometric contraction of the deep and superficial muscles surrounding the cervical spine is present. This increase in stability could be developed to the detriment of the cervical spine flexibility. A previous study discussed the possibility that decrease in amplitude of prop players (the two players situated on the sides of the front row, who frame the hooker during scrums) could be due to an increased fatty mass in the neck area in these players compared to other rugby players.[27] However, this explanation goes against the findings of other researchers who have shown that fatty mass and neck circumference do not play a role in limited cervical range of motion.[28]

An alternative explanation, especially for older players, could be that the decreased range of motion in players compared to controls is due to an early stage, subclinical, articular pathology. Early disc degeneration is found in 56% of front row players, against only 15% of a matched non-rugby control group.[29] In the same study 71% of players were shown to have a disk space narrowing, 36% a herniated disk and 48% a protrusion. In addition, an estimated 80% of rugby players older than 21 years of age develop osteophytes favoring the narrowing of the spinal canal and the development of osteoarthritis due to increased constraint and pressure on the joint system that increases the degeneration and inflammation leading to osteoarthritis.[29]

Comparisons between front row players and players in other positions

The most pronounced differences between front row players and other positions were found for the senior age-category. One explanation for this difference could be that the development of physical capacity of the front row player is initiated during youth and only peaks in seniors, before decreasing in veterans. In addition, the muscular increases seen in the senior pack players can be explained by the practice of weight training which is typical for players wishing to play at a competitive level in the senior category.[30] Among the players in the current study population, 73% of seniors trained in the gym (85% of the front row and pack, 50% of the backs), as compared to only 12% of juniors and 18% of veterans. It is common practice in training schedules for junior and senior (not veterans) playing categories in Belgian elite divisions, for players to have at least one weekly whole body weight training session included in their training schedule. Nevertheless, no training routine is specifically developed to target cervical strength.

An important difference could also be that for senior players contacts are stronger and faster and the scrum rules less protective.[31,32] To minimize the risk of injury, the rules of scrums differ by age category. Pushing in scrums is forbidden before 15 and after 35 years of age, whereas it is restricted to 1.5 meters between 15 and 19 years of age. An adapted cervical musculature is needed to face these severe constraints. The results show that the front row players have a bigger volume and a lesser amplitude of movement than other forward players, and backs. These findings are consistent with a previous study which found that the decrease in the cervical column movement amplitudes scales with rugby training frequency and total years of practice.[33] It is clear that front row players develop their muscles to fight against the forces applied vertically on their cervical spine during scrums.

Clinical Implication

In recent years, rugby injury prevention systems have been put in place, such as New Zealand's "Rugbysmart", Australia's "Smartrugby", South Africa's "Boksmart" and the International Rugby Board's (IRB) "Rugby Ready". They integrate education and training for rugby players, coaches and referees, as well as the medical and club personnel. In particular, they detail the physical preparation for developing the necessary strength, speed, and flexibility during training.

It is generally accepted that stabilization exercises, as well as high-intensity strengthening exercises that increase muscular mass, protect against acute injuries such as fractures or sprains.[34,35] All front row rugby players have high intensity cervical preparation exercises as part of their specific training. However, it has also been shown that high-intensity strengthening exercises can sometimes result in early degenerative diseases of the cervical spine.[36-39] Nevertheless, because of the scrums in rugby, in order to prevent serious cervical injuries in the front row, it remains necessary to strengthen and stabilize the cervical region muscles,[40] so it is important to monitor this appropriately.

These injury prevention systems and high intensity exercises do not, at this time, include any monitoring of cervical muscle size over time to assess the effectiveness of proposed exercises, and more particularly cervical strengthening. From the findings of this study, implementation of cervical ultrasound measurements, with regular follow-ups, could help objectively ascertain the effectiveness of proposed neck strengthening exercises suggested by all injury prevention systems. This may also help define the readiness to play within the different rugby federations (see above "Smartrugby", etc) and could eventually lead to the creation of minimum muscle size standards for playing in the front row.

In addition to the general rugby fitness requirements, in some countries, a specific paragraph of the medical certificate is devoted to "no contra-indications to the practice of rugby in front row position" for amateur championships. Since 2013, in France, a junior player moving into the senior category and wishing to play in the front row must hold a "front row passport", based on physical tests, as well as a cervical MRI in case of cervical history or symptoms.[36] To mitigate injury risk, the Scottish Rugby Federation stipulates that players have to be certified before playing in the front row a specific strength test of the neck.[41]

The rules for scrums have been updated over several years in order to make rugby safer (2007, 2012, 2013 and 2014).[42] Regulations in the youth category aim to avoid or limit the push to 1.50 m, however variations are used within each jurisdiction and for different age categories. Indeed, young people, who first transition into the senior category, find themselves suddenly having to push fully in the scrums, without preparation.[42]

Assessing muscular volumes with ultrasound measurement, as done in this study, can be learned with practice. Prior to use, reliability of the operator should be confirmed by repeated measurements on the same individual and the ability to achieve correct anatomical positioning of the probe as per defined published protocols verified.[14-16] It is a non-invasive and completely safe technique, with no contra-indications. With further research, the measurement protocol developed in this study could become the basis for describing minimal values by age to be reached in order to play in the front row.

Ultrasound imaging could also be particularly useful to capture functional movements in real time[43] or verify the state and evolution of external muscle volume after a traumatic injury before the return of the player to the field. Since previous studies on the size of the muscles do not currently exist, the data presented in this paper can serve as a starting point for future research that may result in a consensus between the international federation and rugby leagues, once correlation to injury is established, by defining a minimum muscle size below which the player cannot get his "front row passport". Below these limits, specific strengthening and stabilization exercises can be put in place for isometric development (as for during scrums), dynamic and proprioceptive, as well as stretching to increase range of motion.[44] The outcome of these and other specific training exercises can also be directly assessed using ultrasound imaging to monitor progress.

Further studies with direct injury outcome correlation should investigate whether adding to the "front row passport", in terms of cervical muscle size (circumference) benchmarking, range of motion amplitudes, and muscle thickness assessed via ultrasound could add to injury prevention. While the discussion is focused on the scrums, tackling remains the second cause of cervical spine injuries[45] and one of most dangerous aspects of the sport.[8] The focus of this study was mainly on front row players, but the above fact could justify implementing cervical muscle monitoring to all players. Finally, it is to be noted that only amateur players were considered in this study, and it would therefore be interesting to implement these measurements with professional players. In so doing, and for expanding on this pilot data to build a comprehensive database, the measurement values in Tables 3–5 could be used to establish minimum sample sizes for powering a future study.

CONCLUSION

Front row rugby players generally have thicker T, SCb and SCOM compared to other players in different positions. The range of motion and muscle size differences observed were even more pronounced in the senior age category, where the rules for pushing during scrums are the most permissive. Both ultrasound and range of motion measurements may complement current pre-participation screening used by rugby federations by objectively monitoring muscular size and motion amplitude around the cervical spine.

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Appendix A. *Post-hoc evaluation of measurement consistency was established by intra-class correlation coefficient calculation from seven repeated measurements ('trials') of all five muscles thicknesses measured in the study, on both the left and right side, of one subject volunteer. For each trial, the average of three measurements was taken, as done during the study. The volunteer was completely repositioned starting from a standing position between all seven trials. The intra-class correlation coefficient, a measure of measurement consistency for continuous data, was then calculated for all ten muscles thicknesses (five left side and five right side) between the seven repeats and found to be 0.98, demonstrating excellent agreement.*

LEFT SIDE

		T	Sca	SCb	SPC	SCOM
Trial 1	measurement 1	0.17	1.00	0.62	0.80	0.88
	measurement 2	0.19	0.96	0.63	0.80	0.89
	measurement 3	0.19	0.95	0.62	0.82	0.85
	Average	**0.18**	**0.97**	**0.62**	**0.81**	**0.87**
Trial 2	measurement 1	0.21	0.95	0.68	0.80	0.78
	measurement 2	0.20	0.95	0.70	0.80	0.78
	measurement 3	0.21	0.96	0.68	0.81	0.77
	Average	**0.21**	**0.95**	**0.69**	**0.80**	**0.78**
Trial 3	measurement 1	0.19	0.94	0.68	0.84	0.85
	measurement 2	0.20	0.95	0.67	0.82	0.86
	measurement 3	0.22	0.95	0.68	0.82	0.86
	Average	**0.20**	**0.95**	**0.68**	**0.83**	**0.86**
Trial 4	measurement 1	0.19	0.94	0.68	0.81	0.88
	measurement 2	0.20	0.94	0.67	0.79	0.87
	measurement 3	0.19	0.93	0.68	0.82	0.86
	Average	**0.19**	**0.94**	**0.68**	**0.81**	**0.87**
Trial 5	measurement 1	0.21	0.96	0.69	0.83	0.81
	measurement 2	0.20	0.95	0.68	0.84	0.83
	measurement 3	0.19	0.96	0.68	0.83	0.83
	Average	**0.20**	**0.96**	**0.68**	**0.83**	**0.82**
Trial 6	measurement 1	0.20	0.96	0.66	0.78	0.78
	measurement 2	0.21	0.96	0.67	0.80	0.79
	measurement 3	0.20	0.97	0.68	0.81	0.79
	Average	**0.20**	**0.96**	**0.67**	**0.80**	**0.79**
Trial 7	measurement 1	0.19	0.98	0.65	0.76	0.81
	measurement 2	0.20	0.98	0.66	0.75	0.82
	measurement 3	0.19	0.97	0.65	0.75	0.81
	Average	**0.19**	**0.98**	**0.65**	**0.75**	**0.81**

RIGHT SIDE

		T	Sca	SCb	SPC	SCOM
Trial 1	measurement 1	0.30	0.95	0.65	0.88	0.71
	measurement 2	0.33	0.96	0.64	0.86	0.70
	measurement 3	0.32	0.94	0.64	0.87	0.71
	Average	**0.32**	**0.95**	**0.64**	**0.87**	**0.71**
Trial 2	measurement 1	0.21	0.94	0.63	0.97	0.71
	measurement 2	0.22	0.95	0.64	0.95	0.72
	measurement 3	0.22	0.94	0.64	0.95	0.71
	Average	**0.22**	**0.94**	**0.64**	**0.96**	**0.71**
Trial 3	measurement 1	0.20	0.97	0.67	0.85	0.70
	measurement 2	0.20	0.96	0.66	0.87	0.71
	measurement 3	0.21	0.96	0.65	0.87	0.70
	Average	**0.20**	**0.96**	**0.66**	**0.86**	**0.70**
Trial 4	measurement 1	0.20	0.97	0.73	0.87	0.71
	measurement 2	0.21	0.99	0.74	0.86	0.72
	measurement 3	0.20	0.96	0.71	0.86	0.72
	Average	**0.20**	**0.97**	**0.73**	**0.86**	**0.72**
Trial 5	measurement 1	0.19	0.89	0.73	0.95	0.71
	measurement 2	0.20	0.90	0.72	0.94	0.72
	measurement 3	0.19	0.91	0.71	0.95	0.71
	Average	**0.19**	**0.90**	**0.72**	**0.95**	**0.71**
Trial 6	measurement 1	0.22	0.91	0.75	0.89	0.74
	measurement 2	0.21	0.93	0.74	0.88	0.73
	measurement 3	0.20	0.94	0.74	0.88	0.72
	Average	**0.21**	**0.93**	**0.74**	**0.88**	**0.73**
Trial 7	measurement 1	0.19	0.97	0.89	0.87	0.71
	measurement 2	0.21	0.98	0.85	0.88	0.71
	measurement 3	0.20	0.98	0.85	0.87	0.72
	Average	**0.20**	**0.98**	**0.86**	**0.87**	**0.71**