The relationship between Musculoskeletal Screening and Injuries in Athletes at the New South Wales Institute of Sport.

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EXECUTIVE SUMMARY

Until recently, musculoskeletal screening at the New South Wales Institute of Sport has been a work in progress. Medical staff and screening processes have been evolving, without a particularly strong concept of the potential for injury prevention.

Data existed from a range of sports doctors and physiotherapists and was often sports specific. Moreover, with changes in staff, the nature of data collected during musculoskeletal screening may have changed from year to year. Records varied within and between professionals.

Through NSW Sporting Injuries funding, 1362 existing musculo-skeletal data records of NSWIS scholarship athletes across nine was compiled. After review the records from a sub-set of sports across the 2002-2007 scholarship years was included in the final analysis.

The analysis identified sports with an increased rate of injury and also injuries that were more common in the sports analysed.

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BACKGROUND

PREVIOUS SCREENING STUDIES AMONG ATHLETES

Medical screening is the routine assessment of the physical and psychological condition of an individual. Screening usually occurs prior to participation in physical activity or employment, to determine a person's capacity to complete specific tasks. Screening can incorporate a number of medical assessments, such as electrocardiographs, cognition/concussion testing, pathological analyses, bone densitometry and musculoskeletal screening.

In previous studies, medical screenings of athletes included factors such as sports-related head injury[4,5], irregular cardiac events[6] and asthma[7]. Reports of sports-specific screening also involved iron status in gymnasts[8], hormone ratios in cyclists[9], and stress fractures in track and field athletes[10]. However, these generally involve a singular medical screening test within a limited sports-specific sample of athletes. More holistic medical screening of large cohorts of athletes is less common in the literature.

MUSCULOSKELETAL SCREENING AMONG ATHLETES

Musculoskeletal screening represents a critical component of medical screening among athletes. Musculoskeletal screening entails a series of physical assessments to determine the health and function of joints, nerves, muscles and other connective soft tissue. Although somewhat limited, results of musculoskeletal screening is available for athletes such as students of physical education and sport science-related disciplines, professional athletes (particularly those within a team or club), and scholarship athletes within a regional, state or national sporting institution.

Musculoskeletal screening for sports can be performed by a variety of personnel such as a coaches, nurses, medical practitioners or allied health professionals. However, musculoskeletal screening should be performed by those with specific training in the orthopaedic sciences. For many athletic populations with routine musculoskeletal screening requirements, such as scholarship holders at the New South Wales Institute of Sport (NSWIS), screening is completed by physiotherapy-trained staff and accredited service providers.

A more thorough and detailed review of musculoskeletal screening literature, current limitations and considerations for future research, can be found in the systematic review developed for this project.

MEDICAL SCREENING AT THE NEW SOUTH WALES INSTITUTE OF SPORT

The New South Wales Institute of Sport (NSWIS) was established in 1996 with 400 athletes and has grown to its current excess of 700 talented high-performance scholarship holders in 31 programs across 24 sports. The institute offers a comprehensive medical program to all scholarship recipients that includes a mandatory screening of athletes for the identification of existing illness, health and musculoskeletal problems.

In 2001/02 an extensive review of the screenings process was undertaken and appropriate changes made. The review resulted in a more streamlined and sport-specific screening protocol. Currently over 100 NSWIS recognised physiotherapists practising within NSW. All of whom are capable of performing musculoskeletal screening on scholarship athletes. Each physiotherapist has been accredited under a closely regulated criteria of excellence in sports medicine knowledge, training and experience.

Each NSWIS athlete is required to complete a thorough musculoskeletal examination under the discretion of an NSWIS accredited physiotherapist, at the commencement of a scholarship and approximately every 12 months, thereafter. The purpose of the routine screenings is to obtain musculoskeletal profiles through the assessment of various physical components such as;

- joint and muscle ranges of motion (ROM),
- indicators of movement control and stability,
- postural and movement alignment, and
- proprioceptive balance.

These assessments help determine any problematic or vulnerable aspects of the athlete's physical condition that could predispose the athlete to injury during participation in training or competition. Musculoskeletal screening protocols at NSWIS contain core screening tests across all sports, as well as particular assessments for sport-specific injury risk identification.

At the completion of the musculoskeletal screening, the NSWIS-accredited physiotherapist considers results from the assessments and often suggests modifications to an athlete's training program or, in severe cases, refers the athlete onto a specialist medical physician. Coaches are alerted of areas of concern and modify the athlete's training program to minimise the risk of injury to the athlete.

NSWIS athletes may be among the most at risk of injury because of the inherent high exposure to training and competition[1]. Reports of injury rates among elite athletes in other states of Australia include the 845 athletes screened from the Queensland Academy of Sport[2] (QAS) as part of a psychological assessment study. Sixty-seven per cent of QAS athletes incurred an injury in the 12 months prior to the screening and 18% were injured at the time of screening. This result indicates the importance of mandatory

musculoskeletal screening as an important component of preventive and treatment athlete services at state-level sporting institutes such as NSWIS.

Over 10 years of testing has lead to the development of a progressive musculo-skeletal screening instrument for athletes in the scholarship program at NSWIS. The instrument is strengthened by periodic tests of reliability by NSWIS screening coordinators. However, to date, no longitudinal analyses of the trends or predictive power of musculoskeletal screening data and their link to injuries have been conducted.

Therefore, within the context of the extensive musculoskeletal screening program at NSWIS, and the sizable collection of data from archived musculoskeletal screening over the past decade, a rare opportunity existed to objectively and longitudinally identify trends for the highest risks of injury in musculoskeletal screenings among athletes.

RESEARCH OBJECTIVES

The aim of this research was to retrospectively investigate risk factors for injury identified through the musculoskeletal screening of scholarship athletes at the New South Wales Institute of Sport (NSWIS). This study was designed to examine trends emerging from routine athlete screening and injury reporting, performed from 2001 to 2008. The desired outcome was to advance the understanding of the role of musculoskeletal screening in injury risk factor identification.

Specifically, the objectives of the research were to;

- Review current literature linking musculoskeletal screening and injury-predictive risk factors, and identify gaps in evidence-based research and inform possible directions with the current study (see Appendix 1).

- Collate NSWIS musculoskeletal screening results and identify descriptive normative data for selected musculoskeletal tests and self-reported injuries within sport-specific, age, and gender groupings.

- Assess if any trends exist between musculoskeletal results and self-reported injuries recorded at the proceeding musculoskeletal examination, approximately 12 months later.

As a result of this research, the investigators believe the study will contribute to the refinement of musculoskeletal screening tools and data collection systems, used at NSWIS as well as at other sporting institutions. In essence a comprehensive investigation of the data may advance the understanding of sports injury prevention for elite athletes.

METHODS

This research project was developed to investigate if a significant association existed between musculoskeletal screening results and athletic injury, using existing musculoskeletal screening information. As the investigators did not require the collection of any new or additional data, this study involved a secondary analysis. As such, participants were not required to provide additional consent, above that gained at the time of screening. (National Statement on Ethical Conduct in Human Research – March 2007). Confidential athlete information was removed from the dataset prior to data analyses and replaced by a code provided by a researcher independent to this project to ensure privacy of information.

The specific objectives of the research were achieved by using a segmented approach to efficiently develop the study. This method provided clear progressive stages to inform the next stage of the study. The segmented steps were to;

- Determine the quantity of musculoskeletal data at NSWIS and selecting the study sample
- Develop a master database of musculoskeletal data using the study sample
- Ensure consistency and similarity between screening data across sports and screening personnel through data checking and cleaning.
- Code current and previous injuries reported by athletes at screening

DETERMINING THE QUANTITY OF MUSCUOLSKELETAL DATA AT NSWIS AND SELECTION OF THE STUDY SAMPLE

Currently over 700 scholarship holders at NSWIS, are required to undergo a musculoskeletal screening examination every 12 months. Records of injury reports and medical examinations of previous scholarship athletes span a decade. To ensure the study remained within the scope of resources available to the research team, it was decided to restrict the number of sports to be included in the study to those sports with larger numbers of athletes across consecutive years. This would dramatically decrease the complexity, number of data points and analyses required to detect any significant trends. The number of musculoskeletal screenings performed at the NSWIS since its establishment, were tallied to assist researchers select sports for inclusion to our study sample.

The number of scholarship sports and corresponding screenings is summarised in Table 1 below;

Table 1: Initial summary of the number of musculoskeletal screenings at NSWIS

	1999	2000	2001	2002	2003	2004	2005	2006	2007	TOTAL (2002+ only)
AWD								16	20	
Baseball			5	32	27	32	35	31	31	**188**
Basketball	6		18	19	16		22	10		**67**
Beach Volleyball					7					
Canoeing - Slalom	1			5		11	4			
Canoeing - Sprint					4			7		
Cricket - Men		7	6	11		19				
Cricket - Women			5							
Cycling			22		1	23		8	1	
Diving			10	13	9	13	3	8	8	
Equestrian		14		17		20	22	1		
Golf			10	12	12	12	12	8	11	**67**
Gymnastics - MAG			7	8	5	4	6		10	
Gymnastics - RG			6	5	3					
Hockey - Men			19	16	10	10	17	19	17	**89**
Hockey - Women			16	14	15	19	22	14	16	**100**
Ice Speed Skating		5	3				2			
Individual Scholarships			7				1			
Lawn Bowls			7		8	6	11	13	18	
Netball		7	19	18	19	17	14	13	23	**104**
Rowing					1	1	16	16	13	
Sailing				7		1	9		15	
Soccer - Men			18	19	25	19		23		**86**
Soccer - Women			19	18	12	12	12	32	31	**117**
Softball			14	11	15	11	2	17	18	**74**
Swimming			23	28	20	11	10	20	15	**104**
Tennis			28	7		10	12	14	16	**59**
Track and Field		16	25	29	38	30	30	31	30	**188**
Triathlon		6	7	6	12	16	5	8	1	
Waterpolo - Men			10	24	20	16	10		9	
Waterpolo - Women			5	14	25	32	10	18	20	**119**
Weightlifting				8	3	6	4	7	6	
Wheelchair Basketball			8	8	11	9	7	10	1	
Wheelchair T & R				8		5	5	2		
Winter Sports			16		11	17			18	
TOTAL (selected sports)				**237**	**234**	**215**	**198**	**250**	**228**	**1362**
PDF documents										
Different Format										
1st preference sports										
2nd preference sports										

AWD- Athletes with Disabilities

From the data in Table 1, the investigators identified the sports with the highest number of musculoskeletal screenings over consecutive years for inclusion in this study, to ensure an adequate sample size the most comprehensive data for analyses. Limiting the number of sports in the study, but maintaining a large sample size, was postulated to increase the likelihood of finding an association between screening results and injury. Furthermore, the tracking of athletes' results over consecutive years was strengthened with larger participant rates.

The following sports were selected for our study sample because they provided approximately equal samples of both male and female participants, and varied greatly in skill and physiological requirements;

- Hockey (men's and women's)
- Soccer (men's and women's)
- Waterpolo (men's and women's)
- Track and field (all disciplines)
- Tennis
- Swimming

Hence, the participants of this study were current and past NSWIS scholarship holders in the sports indicated above, who have completed at least one musculoskeletal screening assessment within the period between 2001-2008 inclusive.

DEVELOPMENT OF A DATABASE OF MUSCULOSKELETAL DATA WITH OUR STUDY SAMPLE

The current project was an opportunity to streamline and advance the format of past and present athlete musculoskeletal screening data at NSWIS. As a direct result, data are currently documented in soft copy form as separate Microsoft Office Word document files. Because the analyses of such a large quantity of musculoskeletal data required the development of a database, much of the study preparation involved the process of transforming hundreds of separate screening data into one comprehensive spreadsheet for analyses.

Consultation concerning the design of a database was sought through the assistance of *Clearwater Solutions Pty Ltd*, a software company with a background in medical database design. Templates of musculoskeletal screening forms were provided to the company for initial database design and development. Files of musculoskeletal screening forms were organised by year and sport before they were provided to *Clearwater Solutions* for data recognition scanning. This process involved the optical scanning of each individual musculoskeletal screening file in softcopy form, by a data recognition program. As a consequence, the data were saved into a single, organised Microsoft Office Excel spreadsheet. Therefore the file housed results for all musculoskeletal screening tests for each sport.

Upon receipt of the database from *Clearwater Solutions*, it was recognised some screening files were duplicated. Table 2 below represents the final sample size after duplicated files were removed and comparable athlete identification was validated.

Table 2: Summary of the final sample size used in the current project

Sport	2001	2002	2003	2004	2005	2006	2007	2008	TOTAL
Hockey - Men		16	10	10	17	23	17	17	**110**
Hockey - Women		14	15	19	22	14	16	11	**111**
Soccer - Men		42	20	19	18	23	14		**136**
Soccer - Women		18	12	12	20	36	28		**126**
Swimming	24	29	20	12	8	16	15		**124**
Tennis	28	7		10	12	14	17		**88**
Track and Field		31	38	37	15	29	32		**182**
Waterpolo - Men	10	24	20	16	9	17	9		**105**
Waterpolo - Women	13	15	25	32	8	18	22		**133**
TOTAL	**75**	**196**	**160**	**167**	**129**	**190**	**170**	**28**	**1115**

DATA CLEANING TO ENSURE CONSISTENCY AND SIMILARITY BETWEEN SCREENINGS

Musculoskeletal screening data were initially organised into separate Microsoft Excel spreadsheets for ease of screening by *Clearwater Solutions. Separate spreadsheets also* ensured efficient cleaning of data. The nature of the NSWIS musculoskeletal data imported into the sports-specific spreadsheets for analyses consisted largely of numerical values depicting the results of numerous musculoskeletal tests. These results ranged from indicating the;

- range of movement at specific joints (indicated in degrees),
- muscle length (indicated in centimetres),
- limb length (indicated in centimetres).

However, some results were indicated through categorical means such as using the descriptors of "poor", "fair", and "good". Due to the evolving nature of the NSWIS screening protocol, a number of test results were indicated through both categorical and numerical data. After consultation with the principal NSWIS physiotherapist, test results of mixed data types were converted to comparable data using a conversion scale, relative to the most prevalent data type for the specific test.

Open text information was also collected during musculoskeletal screening, such as the athlete's name, date of birth, screening information (date, name of screening physiotherapist) and information pertaining to injuries sustained within the previous 12 months, current injuries, posture, muscular and joint issues, walking gait, core stability and flexibility. Much of this information was not used in this project due to the complexity of using open text. However, information within these columns was used to confirm any test results seen to be outside of the normal ranges, which may have otherwise been the result of an alternative measurement technique. This was often cited in tests requiring the use of a goniometer, in which the stationary arm and movement arm or point of measurement reference were often not consistent between screening physiotherapists.

Open text injury data collected by the screening physiotherapist for current injuries and injuries within the previous 12 months were later coded. This is further described in the section below.

Numerical and categorical data were carefully screened to ensure accurate and consistent data. These included;

- Ensuring that no two columns of screening data were results from the same test
- Ensuring tests with similar names were merged into one column, permitted the tests were deemed to be the same
- Ensuring the data in each column (or test) were of the same type (i.e. ordinal or categorical)
- Ensuring that results for each musculoskeletal test were measured in the same unit (e.g. centimetres or degrees)
- Ensuring the results for each musculoskeletal test were within the scope of the expected range indicated on the musculoskeletal screening template
- Ensure results were precise and without other symbols such as < , > or of a range (e.g. 10-15cm)

Cleaning of data was completed following consultation with NSWIS physiotherapists. Specific queries regarding data quality, expected ranges and testing procedures were discussed at a number of meetings as well as through email and telephone correspondence.

To ensure data across the separate spreadsheets from the nine selected sport sets were treated the same, a list of 48 data rules were created and implemented. The rules ensured that variables were corrected in a consistent manner for eventual merging into one fully encompassing dataset for statistical analyses

Once the data from each of the spreadsheets were checked, spreadsheets were carefully merged into a master spreadsheet by carefully creating columns for each of the tests used during musculoskeletal screening and pasting data from each sport into rows according to the specific tests used for those sports. From this process, it became evident that a number of tests with slightly different names were essentially identical to another test with a slightly modified test name. These were considered the same test, provided results occurred within a comparable range.

Once the data were fully merged, information pertaining to the athlete's identity, such as name and data of birth, were modified and used to create a unique and re-identifiable code for database analyses. This code was developed to represent the following;

A_BBB_CC_DD_E

Where,

A = 1st letter of first initial
B = 1st 3 letters of surname
C = date of birth
D = month of birth
E = athlete's screening number in chronological order

This coding system protects the identity of the athlete but still permits data linking between athletes to investigate screening and injury association over consecutive screenings. This code can only be used for

re-identification of the athlete by the primary investigators with access to the original dataset on Microsoft Excel.

CODING OF CURRENT AND PREVIOUS INJURIES REPORTED BY ATHLETES AT SCREENING

Previous and current injury data were obtained by 12-month athlete recall, conducted at the time of screening. This injury history was recorded as an open text field, creating a wide variation in the amount of detail and specific diagnoses indicated. This injury data were coded by the investigators to ensure that injury data were able to be analysed.

The coding system used for this task was The Orchard Sports Injury Classification System (OSICS) Version 10 (v10). The OSICS-v10 system consists of common sports injury diagnoses, organised into groupings that can be collapsed into broader parent categories for easy tabulation for injury prevalence studies. The most commonly used medical coding system, the International Classification of Diseases (ICD) is regarded as inadequate for sports injury studies due to the lack of specific sports injury codes.

All previous and current injuries were independently coded by two members of the research team. Injuries were coded by indicating the most appropriate musculoskeletal parent category according to the OSICS v10 system. The Parent categories were organised by anatomical site with a broad pathology code for each of the musculoskeletal diagnoses. For example, a complete or partial anterior cruciate ligament (ACL) rupture, patellar subluxation, or superior tibio-fibular joint sprain would all fall into the “Knee sprains/Ligament injuries” Parent category. For cases in which post surgical information was indicated, the specific branch for medical codes were used, as were other infrequently occurring medical conditions such as Osgood Sclatters Disease and Spina Bifida.

For athletes reporting numerous injuries, all injuries were coded. Injuries that were reported as bilateral in nature were coded twice to indicate that both left and right limbs were affected.

Coding discrepancies between the two coders were identified and forwarded onto a third (blinded) coder for further consideration.

RESULTS

Table 3 shows the number of athletes in each scholarship year by sport and by the number of years individual athletes were in the NSWIS program. An individual male hockey player and female water polo program were in the NSWIS program for seven years.

TABLE 3: Numbers of athletes in year 1-7 of their scholarship within each sports program.

SPORT	1	2	3	4	5	6	7
Hockey-Men	42	25	21	15	5	1	1
Hockey-Women	45	30	20	12	4		
Soccer-Men	93	39	4				
Soccer-Women	70	35	15	4	2		
Swimming	62	36	19	6	1		
Tennis	62	18	8				
Track And Field	88	58	29	7			
Water Polo-Men	55	26	18	5	1		
Water Polo-Women	56	34	22	15	4	1	1
	573	301	156	64	17	2	2

Table 4 shows the number of athletes within a sport and by gender (where discrete programs) reporting at least one injury as having occurred in the past year of their scholarship. A greater total number of injuries were reported in early years of the scholarship with this being influenced by more athletes being in the NSWIS for between one and three years.

Table 4 shows the number of athletes reporting at least one injury in the past year.

SPORT	1	2	3	4	5	6	7
Hockey-Men	19	10	9	7	1	1	
Hockey-Women	27	22	14	9	3		
Soccer-Men	65	28	3				
Soccer-Women	49	27	10	4	1		
Swimming	23	16	10	3			
Tennis	35	11	4				
Track And Field	55	36	20	5			
Water Polo-Men	25	8	9	2	1		
Water Polo-Women	30	17	13	9	2	1	1
Grand Total	328	175	92	39	8	2	1

Table 5 shows, that when injury numbers are corrected for scholarships a flatter distribution is observed. The percent of athletes reporting at least one injury per year is higher for men's and women's soccer and, women's hockey. Lower rates of reporting occur for men's hockey and men's water polo. The incidence

of at least one reported injury when the data is collapsed across sports and gender appears consistent for the first four years an athlete was on scholarship.

TABLE 5 Percent of athletes reporting at least one injury in the previous year.

SPORT	1	2	3	4	5	6	7
Hockey-Men	45	40	43	47	20	100	0
Hockey-Women	60	73	70	75	75		
Soccer-Men	70	72	75				
Soccer-Women	70	77	67	100	50		
Swimming	37	44	53	50	0		
Tennis	56	61	50				
Track And Field	63	62	69	71			
Water Polo-Men	45	31	50	40	100		
Water Polo-Women	54	50	59	60	50	100	100
Grand Percent	57	58	59	61	47	100	50

Table 6 shows total injuries reported by sports programs. Totals are higher than in table 5 as individual athletes may report more than one injury on presentation at the musculo-skeletal screen. Highest total injuries were reported by men's and women's soccer and, track and field. Lower totals were reported by men's hockey and swimming.

Table 6: Total injury numbers reported by athletes in each year of their scholarship

SPORT	1	2	3	4	5	6	7
Hockey-Men	24	13	11	9	1	1	0
Hockey-Women	33	30	20	13	6		
Soccer-Men	89	35	4				
Soccer-Women	71	36	13	5	1		
Swimming	27	23	13	3	0		
Tennis	58	12	5				
Track And Field	72	51	25	6			
Water Polo-Men	32	9	15	3	1		
Water Polo-Women	39	22	19	11	2	2	3

Injury rates are reported in Table 7. Results are reported as injuries per athlete per year. Women's and men's football reported the highest rate of injury at approximately one injury per athlete per scholarship year. Men's hockey and swimming showed the lowest injury rates per athlete.

Table 7: Injury rates (injuries per athlete) reported for each scholarship year for an individual

SPORT	1	2	3	4	5	6	7
Hockey-Men	0.57	0.52	0.52	0.60	0.20	1.00	0.00
Hockey-Women	0.73	1.00	1.00	1.08	1.50		
Soccer-Men	0.96	0.90	1.00				
Soccer-Women	1.01	1.03	0.87	1.25	0.50		
Swimming	0.44	0.64	0.68	0.50	0.00		
Tennis	0.94	0.67	0.63				
Track And Field	0.82	0.88	0.86	0.86			
Water Polo-Men	0.58	0.35	0.83	0.60	1.00		
Water Polo-Women	0.70	0.65	0.86	0.73	0.50	2.00	3.00

Tables 8 and 9 (presented at end of paper) showing the injury numbers by OSICS classification across sports. In Table 8 the data is presented as totals and represents all injuries reported for that sport by all athels across all scholarship years. Table 9 presents the injuries as a percentage of the total number of injuries for that sport. These tables are labelled “Summary of Raw Data” (Table 8) and “Summary of Relative Data” (Table 9).

PROJECT LIMITATIONS

The major challenge faced by the researchers in this project was that dues to the evolution of the screening programs a number of data records lacked consistency between years over the ten years of data collection. This caused an increase in the time to code and a slow process in aligning data across years and across sports through extensive manual data entry and cleaning of the data. The volume of data was much greater than expected and changes in the musculoskeletal screening professionals over time created inconsistencies in data sheets

Ultimately, without full time staff, the project has suffered from being a lower priority than originally anticipated and new staff required extensive training in order to maintain the integrity of the newer database

BENEFITS

This study has led to a further improvement of screening programs at the NSWIS and a consistent terminology in the musculo-screening information.

The project has allowed the identification of the more common injuries within and across sports and will allow medical and strength and conditioning staff to work with coaches and athletes to develop preventative programs and to identify areas that may require increased attention within musculo-skeletal screening programs.

The project has generated interest from the AIS and a request for information from this project to flow into the National Sport Science Quality Assurance Program (NSSQA) program to improve the musculo-skeletal screening of athletes at the AIS and state Institutes and Academies of Sport

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