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SHARPENING THE SHARPENED ROMBERG

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Key Words

Decompression illness, investigations, treatment.

Abstract

The Sharpened Romberg Test (SRT) is a test of balance commonly used in Diving Medicine. Interpretation of an abnormal test can be confounded by

several factors. This study was conducted to further evaluate the usefulness of the SRT.

In the first part of the study, naval and civilian volunteers in a Naval Base were recruited as subjects. The SRT scores were recorded in two separate trials; once in the morning (4 attempts) and once in the evening (4 attempts) to evaluate the effect of practice on the SRT.

In the second part of the study immediate pre- and post-dive scores in a group of divers were measured to evaluate: (1) the effect of decompression; (2) the effect of the normal post-dive fatigue'; and (3) the vestibular effect of swaying after a boat ride. Comparisons were also made between the distributions of the SRTs of the normal subjects and those of a retrospective group of DCI patients treated at the Slark Hyperbaric Unit, Royal New Zealand Navy Hospital (RNZNH), Auckland.

The SRT was found to have an early learning effect. Second attempts were significantly better than the first ($p<0.001$) within the same trial. However this learning effect plateaued by the third and fourth attempts. No difference was found between trials (morning and evening).

There was a post-dive decline in the scores of the first attempts only ($p<0.05$). Subsequent second to fourth attempts were not affected by diving. The practice effect is only evident between the first and second attempts within the same trial but not between trials. The pre- and post-dive data showed that the SRT was not affected by decompression, post-dive fatigue or the vestibular sensation of swaying that is commonly experienced after a boat ride.

Comparison of the distributions between controls and DCI patients showed a bimodal pattern. Fifty-four percent (54%) of the DCI patients had 'normal' scores (60 seconds), while 14% had scores between 16-35 seconds and 32% scored less than 15 seconds. In contrast, 95% of the control groups had 'normal' scores while 5% scored between 16-35 seconds. Therefore, accepting a score of less than 40 seconds as being "abnormal" will give the SRT a sensitivity of 46%, specificity of 95% and predictive value of 82%.

Introduction

Decompression Illness (DCI) is a multi-system pathological entity with a myriad of presentations.[1,2] Initially DCI was first described in caisson workers and then in divers, aviators and astronauts. Limb pain was the predominant symptom in these groups of patients.[3-7] Over the past three decades published reports of DCI have mainly been from the recreational diving population.[8-13] This is due to the increasing popularity of the sport worldwide. Neurological involvement, especially those referring to the spinal cord and vestibular system, appears to be more common in this group of divers.[2,14-16] Animal studies have shown that, in the spinal cord, bubbles and haemorrhage were seen predominantly in white matter and tended to be most conspicuous in the lateral and dorsal columns.[17,18]

Manifestations of neurological DCI range from mild, subjective symptoms to the dramatic presentations of unconsciousness, paraplegia or quadriplegia. In practice, divers commonly present with subjective complaints, often with little or no objective evidence of neurological abnormalities.[9] It appears that the clinical neurological examination lacks the accuracy to detect the diffuse and multilevel pathology seen in decompression illness. Therefore, the diagnosis of DCI requires a high index of suspicion, and a history of recent diving or exposure to raised environmental pressure.[19]

The usefulness of the Sharpened Romberg Test (SRT) as a clinical marker of DCI was recently highlighted, especially in cases where the disease process was in question.[20,21] Almost 49% of the 35 cases with DCI in that series were found to have grossly abnormal SRT scores with seventy percent (70%) of these achieving a 'normal' score after completion of hyperbaric treatments. Therefore, in this series at least, the SRT score was useful as a quantifiable sign in 50% of the cases.

The Sharpened Romberg Test

The classical Romberg Test as described by Moritz Romberg (1795-1873) is routinely used in neurology to assess proprioceptive loss. It is, however, not sensitive to vestibular or cerebellar impairment.[22,23] Barbey described the first modification of this test in 1944[24] and Fregly, in the late 1960s, employed this "sharpened" Romberg Test (SRT) together with his ataxia test battery as measurements of vestibular impairment at the US Naval Aerospace Medical Institute.[25,26] Also known as "Tandem Romberg"[27] or "Modified Romberg",[28] the SRT has also been employed in several ataxia test batteries in gerontology and toxicology.[29-32] Dr Carl Edmonds introduced its use to Australian diving medicine in 1974 as an alternative to the classical Romberg Test, as it is more sensitive to proprioceptive and vestibular impairment. Since then the SRT has found wide acceptance in the routine assessment of diving patients.[33-35]

Variations in the SRT

The Sharpened Romberg Test, as originally described by Fregly, involved the subject "standing on the floor with eyes closed and with arms folded against chest, feet aligned in strict tandem heel-to-toe position, and body very nearly, if not completely, erect for a period of 60 seconds. A maximum of four trials were administered."[23,36]

Several variants of the SRT have since been described. Some involved the subject having to stand in the usual tandem heel-to-toe fashion but with arms strictly by the side.[28,29,37] Others allowed the subject in this position to freely move his arms in order to regain posture.[30,31] The SRT has also been performed with subjects standing on narrow wooden rails in order to lower the 'ceiling effect'.[38] One investigator proposed that the SRT should be performed with the head tilted.[33]

Factors affecting the SRT

Although the SRT is a sensitive test of proprioception, its specificity in DCI is not clearly defined. Being a test of static postural equilibrium, the SRT is affected by several factors other than dorsal column or vestibular diseases.

AGE AND GENDER

Studies have confirmed that the SRT performance worsens with advancing age. [24-26,29,31] Decline in performance generally begins between the age of 30-40 years in males and as early as 30 years in females.[25,39] The reasons for these gender differences are unknown.[23] The number of females tested was generally small[25] and in selected groups[29] and therefore the finding should be interpreted with caution, especially as one study failed to demonstrate a difference.[28]

LEARNING EFFECTS

Like many tests of performance, SRT scores can improve with subsequent attempts due to a learning or practice effect. Thomley et al. had 18 subjects practise on the SRT twice a day for five consecutive days.[40] Both learning and ceiling effects were reported but the tests were stable over trials. Other studies have shown similar results.[28,25] Briggs et al. found that the majority of their subjects obtained the maximum balance times (60 seconds) in the first trial.[29] A minimum of three trials appeared to provide a good indicator of balance capabilities. The most consistent and sensitive means of measuring the SRT is to record the best score out of 4 attempts.[20,30,31]

FOOTWEAR

No difference was found between wearing shoes or being barefooted.[29] However, shoes with soft soles (such as tennis/basketball shoes) are generally not to be worn because soft surface conditions (which would include foam mats on the floor or thick carpets) distort proprioceptive input and hence would not suitable.[23,26,37]

DOMINANCE

Some investigators required the subjects to perform the SRT with the dominant leg behind. However, in one study no effect of dominance was found.[29]

ACTIVITY LEVEL

In a study that employed self-reported questionnaires, a significant effect was found between activity level and balance performance (including the SRT).[31]

The SRT in diving medicine

Maintenance of postural equilibrium is a dynamic process in which visual, vestibular and somatosensory (proprioceptive, cutaneous and joint) information are integrated with muscular and skeletal responses to maintain the body's position over the base support. The Romberg test assesses the vestibular and somatosensory contribution to balance by eliminating the visual input. The Sharpened Romberg Test (SRT), by having the subject stand heel-to-toe, makes further demands on the vestibular and somatosensory systems by narrowing the base support. It is generally more difficult to perform and is therefore more sensitive to processes that interfere with these systems.

In the context of diving medicine, the SRT appears to be a useful quantifiable sign. In the study by Fitzgerald, the substantial improvements (70%) in the SRT post-treatment scores indicate that DCI causes a deterioration in the SRT.[20] However, other factors which affect the balance system could also contribute to this deterioration of the SRT score. These are summarised below.

a Divers conducting their dives from a boat out in open sea frequently experience persistent vestibular symptoms, described as a sensation of swaying motion, on returning to land. This might adversely affect the SRT performance of a diver presenting for assessment.

b Improvements in the SRT score seen in divers being assessed in sequence (pre-, during and post-treatment) could be due to a learning effect rather than an indication of the actual resolution of the disease being treated.

c Decompression per se (which is known to produce asymptomatic bubbles) or feelings of fatigue after diving could, in theory, affect the SRT.

d Improvements in the SRT score during and after recompression treatment could be due to an effect of hyperoxia rather than a resolution of disease.

e Alcohol consumption is common during most dive trips, and could confound the SRT score.

The aim of this study was to further define the usefulness of the SRT in diving medicine by testing the following hypotheses :

1 The SRT is resistant to the effect on the vestibular system caused by rocking motion of a boat.

2 Scuba diving and decompression per se has no effect on the SRT

3 The recommended protocol used for scoring the SRT is not affected by practice

4 The normal feeling of fatigue post-dive does not affect the SRT score.

Attempts were also made to determine the SRT score or test method which could distinguish between the normal (non-DCI) and the DCI patients.

Methods

This study was conducted in three parts. The first part involved the prospective review of SRT scores in a group of volunteers from Naval and civilian personnel at the Naval Base in Auckland. This group consisted of both divers and non-divers. The second part involved the pre- and post-dive evaluation of the SRT scores in a group of divers. Finally, the SRT scores of the patients with DCI treated at the Slark Hyperbaric Unit (SHU), Auckland, between May 1996 to April 1997 were reviewed.

In part one of the study, the subjects were "captive volunteers" actively recruited by the author. Each subject received an explanatory letter and gave written consent for participation. Divers were entered into the study only if they had not dived for the past seven days and had no history of decompression illness. Exclusion criteria were the same as those in the study by Fitzgerald.[20] A subgroup of 47 participated in 2 separate tests: once in the morning (4 attempts) and once in the evening (4 attempts).

The second part of the study was conducted at the dive site. Divers attending a conference were briefed during registration and participation forms distributed. Baseline SRT scores for divers going for their dives were measured before the commencement of the diving activities. The post-dive SRT scores were recorded for the same individuals within 24 hours after their day of diving. All dives involved a boat ride to the dive location in open sea for the day. Sea conditions were mild to moderate for those dives. Participants were instructed not to consume alcohol for at least 12 hours prior to the tests.

Comparisons were also made between the scores of the control population and a retrospective group of DCI patients treated at SHU between May 1996 and April 1997.

The Sharpened Romberg Test in this study was done with subjects barefoot or wearing flat shoes standing on a flat surface. They stood heel-to-toe with their arms folded across the chest and eyes closed. The test procedure was similar to that proposed by Fregly[29] except that the best score of the 4 attempts was used. Timings were stopped once the subjects lost balance, opened their eyes, moved their feet to regain posture or when the required 60 seconds was attained. The test was discontinued when the score of 60 seconds was obtained on any one attempt. If the subject scored less than 60 seconds, the number of seconds attained was recorded and further attempts made until a score of 60 was attained or up to a maximum of four attempts had been made. Attempts scoring less than 5 seconds were considered as false starts and not recorded.

The data collected were entered into Microsoft Excel version 5.0 and analysed using SPSS for Windows. Distribution scores for balance tests are generally skewed. Statistical tests of significance for age were performed using T-Test while those for SRT scores were analysed using Mann-Whitney U Test and Wilcoxon Signed Rank Test for independent and paired samples respectively. An alpha level of 0.05 was set as the criterion for all tests of statistical significance.

Results

Sharpened Romberg Test data were obtained from 102 subjects. One subject with a history of lower limb pathology was excluded from the study. Forty eight of the subjects were divers with no known history of DCI and 53 were non-divers. Forty-seven subjects had two separate measurements of their SRT trials.

Table 1 summarises the age distribution of the study population. Divers in the under 40 age group were generally older than the non-divers. The age distributions of those in the 40 and over group were the same. A comparison of the SRT scores between the divers and the non-divers showed no significant difference (Table 2). This is despite the divers in the over 40 group having an older mean age .

Each subject was allowed 4 attempts per trial to attain a score of 60 seconds. From the study sample of 101 subjects it was found that 71% attained the required 60 seconds at the first attempt, 89% by the second, 93% by the third and 95% by the fourth attempts (Figure 1). A

TABLE 1

AGE DISTRIBUTION OF 101 CONTROL SUBJECTS

Age group	Subjects	Number	Mean Age + SD	t-test
< 40 yrs	Divers	29	30.34 + 7.44	$p < 0.05$
	Non-divers	40	22.45 + 6.68	
≥ 40 yrs	Divers	19	48.26 + 7.76	Not significant
	Non-divers	13	47.85 + 6.65	

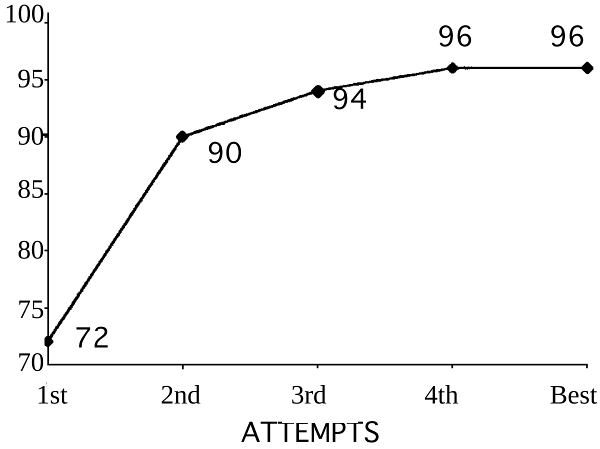

Figure 1. The number of controls scoring the maximum (60 seconds) in each of the four attempts during the trial.

TABLE 2

SIGNIFICANCE OF SHARPENED ROMBERG TEST SCORE DIFFERENCES

Ages	**Subjects**	**Attempts First**	**Attempts Best**
< 40 yrs	Divers Non-divers	*Not significant	*Not significant
≥ 40 yrs	Divers Non-divers	*Not significant	*Not significant

*Mann-Whitney U Test

significant difference ($p < 0.001$; Wilcoxon signed ranked sum test) was found between the scores of the first and second attempts. Comparison of the scores between the second, third and fourth attempts showed no significant differences ($p>0.05$).

Figure 2 shows the subgroup (N=47) who had their SRT scores recorded on two separate occasions. No significant difference was found when scores of Trial A (first) and B (second) were compared ($p>0.05$; Wilcoxon Signed Rank Test).

Among the group of divers who had their pre- and post-dive SRT scores measured, the data (Figure 3) showed a post-dive decline in the scores of the first attempts ($p<0.05$). The subsequent second, third and fourth attempts were not affected by diving.

A total of 66 cases of DCI were treated at the Slark Hyperbaric Unit, Auckland in the period between May 1996 to April 1997. Case records were available for 55 patients.

Of the 55, five had no SRT scores recorded and these were not included in the study. Figure 4 compares the

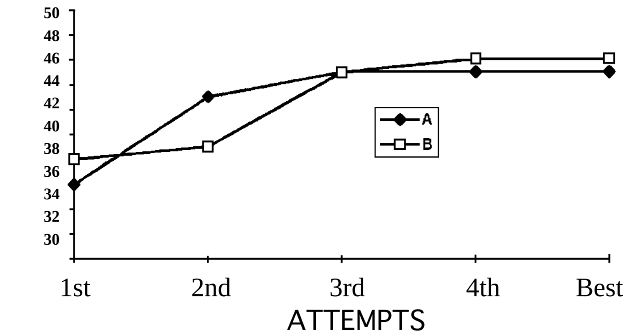

Figure 2. SRT scores of 47 controls tested twice. A denotes the first trial and B the second.

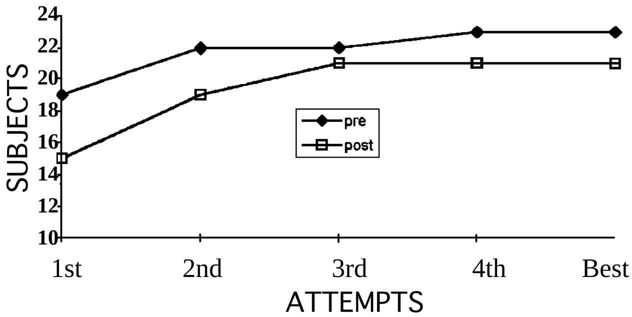

Figure 3. Comparison of the pre-dive and post-dive SRT scores. The number of divers achieving the maximum score (60 seconds) is indicated.

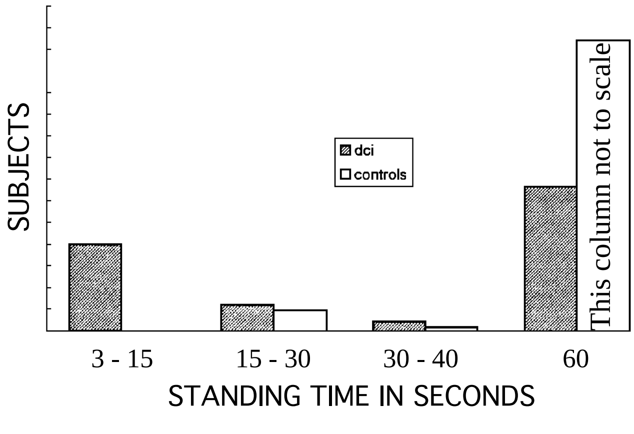

Figure 4. Distribution of SRT scores among patients with DCI and controls

difference in distribution of the SRT scores between the control subjects and those with decompression illness. The performance in the Sharpened Romberg Test in all non-DCI subjects studied (n=101) showed a bimodal distribution with a large majority (95%) achieving a score of 60 seconds and 5% scoring between 16-35 seconds (Figure 4). The patients with DCI also showed a bimodal pattern, with 54% obtaining a score of 60 seconds. The 23 patients who had abnormal SRT scores did poorly with 16 (70%) scoring

TABLE 3

SRT RESULTS IN 23 PATIENTS WITH DCI PRESENTING WITH ABNORMAL SRT

Number of patients	SRT scores Admission	Discharge
9	<= 5 seconds	60 seconds
4	6-10 seconds	60 seconds
3	11-15 seconds	60 seconds
4	16-25 seconds	60 seconds
1	26-30 seconds	60 seconds
2	31-35 seconds	60 seconds

SRT scoring was the best of 4 trials or until 60 seconds were achieved.

less than 15 seconds. The scores of all the patients with DCI who had abnormal scores were less than (or equal to) 35 seconds.

Table 3 shows the SRT scores on admission and on completion of treatment. All patients in this series with abnormal SRT scores on admission had 'normal' scores (60 seconds) upon discharge.

Discussion

The Sharpened Romberg Test is commonly used in the assessment of divers with decompression illness (DCI). In DCI the balance system is involved in a large proportion of patients. Therefore, if found to be abnormal, the SRT is useful as a clinical sign to monitor the progress of the disease during treatment, especially when the patient has only subjective symptoms. However, interpretation of an abnormal SRT score in a diver requires that the attending clinician be aware of other factors which could or could not affect the SRT.

Balance tests are known to improve with practice,[25,29,40] just like any other tests in which skills are involved. In our study population (N=101), the learning effect was evident only between the first and the second attempts within the trial. The subgroup (N=47) which had two separate trials assessed showed no significant difference in their SRT scores. The SRT protocol used appears to provide a good indicator of balance capabilities. Repeat administration of the test showed no learning effect and therefore will not bias the sequential assessment of a patient being treated for DCI.

The pre- and post-dive data (N=25) provided answers to three questions. First, decompression per se causes no deterioration in the SRT score. Therefore, the SRT is probably not a useful or sensitive indicator of decompression stress, be it asymptomatic venous bubbles or subclinical DCI. Second, the feeling of tiredness that divers often experience after diving had no effect on the SRT scores in our study population. Therefore the tiredness that accompanies scuba diving (after 2 dives a day in this context) and the fatigue commonly reported by divers with DCI appear to be pathophysiologically different. Third, the residual vestibular effect (sensation of swaying) after a boat ride in open sea does not cause a significant deterioration in the SRT. However, exposure to severe storm conditions at sea is known to produce a deterioration in balance performance.[41] Only the first post-dive attempts in the sharpened Romberg test were adversely affected (Figure 3). Performances in the subsequent attempts were unchanged from the pre-dive scores.

The distribution of the SRT scores showed a bimodal distribution in both non-DCI controls as well as in those with DCI (Figure 4). However, the majority of patients with abnormal SRT generally had very low scores, with 70% (16/23) scoring less than 15 seconds. There is a considerable overlap in those scoring between 16 to 35 seconds (7 in the DCI group and 5 in controls). It is noteworthy that none had scores between 36-59 seconds. All the subjects who scored more than 36 seconds initially managed to obtain the criterion score of 60 seconds within the allotted 4 attempts. 95% of the normal controls attained the required score, with 5% false positive rate.

TABLE 4

VALIDITY OF THE SRT IN DCI

	DCI	Controls	Total
Abnormal SRT*	23 (21)	5 (4)	28 (25)
Normal SRT*	27 (29)	96 (97)	123 (126)
Total	50	101	151

*Accepting a cut-off score of 40 seconds (in parenthesis) rather than 30 seconds will improve the sensitivity of the test. See text for details.

The 2 x 2 contingency table in Table 4 attempts to define the validity of the SRT. Accepting a SRT score of <=40 seconds as being abnormal would have a sensitivity of 46%, specificity of 95% and a predictive value of 82%. If a score of <= 30 seconds is taken as abnormal, the sensitivity of the test would be reduced to 42% with little change in specificity (96%).

The SRT is resistant to the influence of the factors that were studied , namely practice effect, decompression stress (including post-dive fatigue or tiredness) and vestibular disturbance after a boat ride in mild to moderate sea conditions. Deterioration in SRT scores due to DCI was characteristically in the 16 seconds or less group. If the cut-off score is increased to 40 seconds the sensitivity will be increased to 46% and specificity 95% (Table 4). It is proposed that the scores of all the attempts should be noted down although only the best result is taken as the SRT score. This is to facilitate future research in this area.

The number of patients used in this study is small and therefore extrapolation of the results to diving medicine in general should be made with caution. For practical reasons the SRT procedure used in this study imposed a limit of 60 seconds as the maximum score. Except for those who scored less than 60 seconds, the true SRT scores for those who attained the 60 seconds were probably much higher. This ceiling effect limits the ability of the SRT to detect small decrements in performance score.

Alcohol is another factor which may interfere with the SRT assessment of diving patients. Fregly and Graybiel found postural equilibrium to be highly sensitive to moderate doses of alcohol (2.2 cc 100-proof vodka per kg body weight).[42] Hyperoxia per se, instead of disease resolution, could be another possibe cause of the improvement seen in SRT scores of the patient treated in the chamber. Further studies should be conducted to evaluate the effect of hyperoxia and lower doses of alcohol on the SRT performance in normal subjects.

In summary, the Sharpened Romberg Test is a useful marker of Decompression Illness. The results of this study show that it is resistant to several potentially confounding factors which are often present during the assessment of a diver with DCI, namely, post-dive fatigue, decompression stress, vestibular disturbance resulting from exposure to swaying motion of dive boat and improvements due to practice or learning effect.

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