Clinical utility of dipstick urinalysis in assessing fitness to dive in military divers, submariners, and hyperbaric personnel

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Abstract
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Introduction: Routine dipstick urinalysis is part of many dive medical assessment protocols. However, this has a significant chance of producing false-positive or false-negative results in asymptomatic and healthy individuals. Studies evaluating the value of urinalysis in dive medical assessments are limited.
Methods: All results from urinalysis as part of dive medical assessments of divers, submarines, and hyperbaric personnel of the Royal Netherlands Navy from 2013 to 2023 were included in this study. Additionally, any information regarding additional testing, referral, or test results concerning the aforementioned was collected.
Results: There were 5,899 assessments, resulting in 46 (0.8%) positive dipstick urinalysis results, predominantly microscopic haematuria. Females were significantly overrepresented, and revisions resulted in significantly more positive test results than initial assessments. Lastly, almost half of the cases were deemed fit to dive, while the other half were regarded as temporarily unfit. These cases required additional testing, and a urologist was consulted three times.
Conclusions: To our knowledge, this is the most extensive study evaluating urinalysis in dive medical assessments. In our military population, the incidence of positive test results is very low, and there have not been clinically relevant results over a period of 10 years. Therefore, routinely assessing urine in asymptomatic healthy military candidates is not cost-effective or efficacious. The authors advise taking a thorough history for fitness to dive assessments and only analysing urine when a clinical indication is present.

Introduction

When immersed or submersed, the human body is exposed to unique environmental factors that require specific physiological adaptations.[1] However, certain pre-existing medical conditions may interfere with these compensatory mechanisms, increasing the risk of adverse diving events.[2] It is, therefore, strongly recommended that professional divers undergo a medical examination to determine their fitness to dive.[3,4]

While cardiovascular and pulmonary disease can predispose a diver to severe diving-related illnesses, other organ systems can cause significant problems when diving.[1,2] Regarding the urogenital tract, renal calculus disease, commonly known as kidney stones, can cause incapacitating symptoms. However, until symptoms reveal themselves, microscopic haematuria can be the only sign found when screening 'healthy' subjects.[5] However, haematuria can also be found in athletes, especially in non-contact sports and running, and has little clinical significance.[6,7] Aside from haematuria, dipstick urinalysis can also be used to screen for diabetes mellitus (glucose) or urinary tract infections (nitrite or leukocyte esterase), all of which can have a severe impact on diving safety but rarely present without symptoms. There is no consensus in the field of urology regarding the added value of dipstick urinalysis in asymptomatic individuals.[8] The European Diving Technology Committee guideline recommends routine dipstick urinalysis for blood, protein, and glucose; however, false-positive and false-negative results are typical with this test.[8,9]

In the Netherlands, dipstick urinalysis is required by legislation as part of a medical assessment for fitness to dive; however, its role in such a screening program has not been evaluated.[10] Although this method is highly sensitive in detecting haematuria or glucosuria, its sensitivity for detecting proteinuria is much lower.[11] As a result, dipstick urinalysis should not be the sole test to identify renal target organ damage. False-positive results can trigger costly and potentially harmful procedures such as cystoscopy, while false negatives may create a false sense of safety

among subjects.[12] Using a test with these limitations when screening a generally healthy population, such as occupational or military divers, warrants an assessment of its cost-effectiveness. To our knowledge, a single study (only appearing as a conference abstract) was conducted on this matter, which concluded urinalysis is not cost-effective and has little contribution to diving safety.[13]

This retrospective study endeavours to ascertain dipstick urinalysis' clinical value and cost-effectiveness in conjunction with subsequent referrals from medical assessments of military divers' fitness to dive. We hypothesise that the routine use of dipstick urinalysis in these assessments rarely identifies clinically relevant disease.

Methods

The methods for handling medical information comply with national and European legislation and the guidelines of the Association of Universities in the Netherlands.

CONTEXT

The Royal Netherlands Navy Diving Medical Center is responsible for the medical well-being of the Dutch armed forces' divers, submariners, and hyperbaric personnel. As mentioned in the introduction, the aforementioned group is subjected to annual medical assessments as part of national legislation.

DATA COLLECTION

Subjects gave written informed consent at the time of their dive medical examination consent to use their data for scientific research. Subjects that refused reuse of their data were excluded from the study. All assessments in a 10-year time frame between 2013 and 2023 were eligible for inclusion. Data from urinalysis and baseline characteristics and outcomes of the assessments were extracted from the medical records. The dipstick urinalysis results were coded into five groups: fit to dive, temporary fit to dive, temporary unfit to dive, unfit to dive, and 'other'. This last group includes divers who withdrew from the assessment. This is relevant, as an 'unfit' result from an assessment can have legal or financial consequences for the candidate; many candidates choose to withdraw from the assessment process when a 'fit' result is unlikely. As part of the outcome of the assessments, details such as repeated testing or referral to a urologist were recorded.

DATA ANALYSIS

All data were recorded in a database. Binary data were tested using χ^2 or Fisher's exact tests (or the Fisher-Freeman-Halton test when contingency tables are more extensive than 2 x 2). Continuous data were tested using unpaired *t*-tests or Mann-Whitney U, depending on the normality of the data. Statistical analyses were performed using SPSS Statistics for Windows software (IBM Corp; Armonk, NY: 2022, version 29.0), with $P < 0.05$ defined as statistically significant.

Results

In total, 5,899 medical assessments were performed; about two-thirds were divers, a quarter were hyperbaric personnel, and the rest were submariners. The median age was 32 yr (interquartile range [IQR] 27–40 yr) and 92.8% were male, with 10.5% smokers. About one-fifth were initial assessments (i.e., someone being medically cleared for the first time); the rest were revisions. More details can be found in Table 1.

In this population, 46 cases (0.8%) had a positive result on dipstick urinalysis. Notably, this was significantly more likely in female candidates (Fisher's exact test; $P = 0.004$). Age, height, weight, and smoking status were not significantly different in the positive cases when compared to the total population. Divers were significantly over represented and submariners were underrepresented in this case series, with a *P*-value of 0.007 when tested with a Fisher-Freeman-Halton exact test. Of note, the ratio between divers and hyperbaric personnel was not significantly different when submariners were excluded from the analysis. Lastly, a positive urinalysis result was significantly less present in initial assessments (χ^2; $P = 0.010$), with only two positive tests in 1,129 initial assessments (0.17%).

Of the total population, about two-thirds were deemed fit to dive. Of the remaining one-third, the majority fell in the 'other' category (as explained in the methods section). Interestingly, all 'temporarily unfit' verdicts ($n = 21$) were due to a positive urine test, which represented about half of the cases with a positive result on urinalysis. Aside from a small group, the other half of the cases with a positive urine sample were deemed fit to dive. The differences in results of the diving medical assessment were statistically significant (χ^2; $P < 0.001$)

The relation between the fitness to dive results and the results of the dipstick urinalysis is displayed in Table 2. Erythrocytes were found in more than half of the cases. None of the urinalysis results were significantly more present in any of the fitness outcome groups when tested using Fisher-Freeman-Halton exact tests. Additional investigations were performed in 27 cases (59%) of the 46 positive urinalysis results. Note that these 46 cases belonged to 28 individuals, meaning some had positive test results on multiple assessments (up to five in one case). Of the 27 cases where additional investigations were performed, five were deemed fit to continue diving, 21 were temporarily unfit, and one candidate withdrew from the assessment. Three cases were referred to a urologist, who cleared the diver after additional investigations (repeated urinalysis and cystoscopy in one case). Regarding the individuals with

Table 1
Baseline characteristics and results of diving medical assessments; data are number (%) or median (interquartile range [IQR])

Parameter	Total (n = 5,899)	Cases (n = 46)	P-value
Baseline characteristics			
Sex	5,473 male (92.8%)	37 male (80.4%)	0.004
Age (yrs)	32 (IQR 27–40)	30 (IQR 27–39)	0.540
Height (cm)	183 (IQR 178–188)	181.5 (IQR 173.7–185.2)	0.241
Weight (kg)	85 (IQR 79–92)	79.5 (IQR 71.7–84.2)	0.701
Non-smoking	5,280 (89.5%)	38 (82.6%)	0.142
Type			
Diver	3812 (64.6%)	38 (82.6%)	0.007
Submariner	656 (11.1%)	0	
Hyperbaric personnel	1,431 (24.3%)	8 (17.4%)	
Assessment			
Initial	1,129 (19.1%)	2 (4.3%)	0.010
Revision	4,770 (80.9%)	44 (95.7%)	
Result			
Fit	3,965 (67.2%)	22 (47.8%)	< 0.001
Temporarily fit	352 (6.0%)	0	
Temporarily unfit	21 (0.4%)	21 (45.7%)	
Unfit	91 (1.5%)	0	
Other	1,470 (25.0%)	3 (6.5%)	

Table 2
Influence of urinalysis result on fitness to dive; none of the tested parameters showed statistically significant differences between the result categories (using the Fisher-Freeman-Halton exact test)

Parameter	Fit (n = 22)	Temporarily unfit (n = 21)	Other (n = 3)
Protein	4	3	0
Erythrocytes	15	12	1
Haemoglobin	0	2	0
Leukocyte esterase	5	2	2
Nitrite	2	1	0
Glucose	0	2	0
Ketones	1	0	0
Bilirubin	2	1	0
Urobilirubin	1	2	0

positive test results that were deemed fit for diving; in this retrospective study if it could not be determined whether the positive dipstick was missed by the clinician, or it was noted by the physician but failed to take action accordingly, or perhaps due to other reasons.

Discussion

Our evaluation of nearly 6,000 dive medical assessments of military divers, submariners, and hyperbaric personnel showed a low incidence (0.8%) of positive urinalysis test results. Moreover, these positive test results had limited effect on the end result of the assessment, with almost half of the candidates being cleared for diving and the other half being regarded as temporarily unfit for diving. Repeating urinalysis, additional investigations, or referral to a urologist were performed in these cases without identifying clinically significant disease. Female candidates were overrepresented in the identified cases.

In general, false-positive and false-negative test results are a major issue with screening asymptomatic, healthy, and relatively young individuals with an instrument of limited sensitivity and specificity – and this is also the case in dipstick urinalysis, even though the range of these characteristics varies in different studies.[14] While more advanced techniques, such as imaging (ultrasonography or computer tomography; for nephro- or urolithiasis) or blood analysis (for diabetes) generally may have better test characteristics, there is still a risk of false-positive and false-negative test results with a very low *a priori* probability of disease.[15] Moreover, these instruments can have more impact on the assessment regarding associated costs or harm for the candidate (i.e., radiation in CT-imaging or an invasive test), with an unknown reduction of incorrect test results.

The incidence of positive test results on urinalysis is lower than found in a retrospective study amongst pilots, with the caveat that our population was slightly younger.[16] This, in combination with a generally non-smoking population, could explain the lower incidence of microscopic haematuria

than in the general population.[17] We found a slightly higher incidence of positive results on urinary dipstick analysis in females than in males. However, this is also seen in the general population, commonly associated with cystitis (e.g., with positive nitrite or leukocyte esterase), in contrast to our female population with mainly microscopic haematuria.[18] While this can be related to the menstrual cycle, we feel that we cannot rule out exertion haematuria in our population.[6] Therefore, the authors suggest taking a thorough history for dive medical assessments and only analysing urine when a clinical indication is present.

While urinary dipstick analysis is relatively cheap (generally less than $5 per test), the expenses associated with additional investigations and 'operational downtime' for a diver should also be considered. The latter is particularly relevant for our armed forces but is likely to also be of concern for commercial diving operations. Without clinically relevant findings over a ten-year period, the cost-effectiveness is unfavourable, as was also concluded by the previously mentioned study.[13] We would like to encourage the scientific community to repeat our study, perhaps even prospectively, to validate our findings and discuss the value of urinalysis in asymptomatic divers and hyperbaric personnel.

STRENGTHS AND LIMITATIONS

To our knowledge, this is the largest study to date evaluating the utility of urinalysis in dive medical assessments. While the results strongly indicate that urinalysis is of little value for dive medical assessments, some limitations must be addressed.

Firstly, our population of military personnel has been medically assessed at least once (when entering the service, several units require additional medical screenings) and are of above-average physical fitness. This may have reduced the incidence, and thus the *a priori* chance, of urinary calculi or diabetes. Therefore, our results may not be transferable to other populations, such as commercial or recreational divers.

Secondly, while we could include almost 6,000 assessments, it remains a retrospective analysis of our database. Diabetes, renal calculus disease, and other diseases are the subject of active inquiry when taking a history. However, candidates could have forgotten or withheld information in the dive medical assessment, masking the true incidence of these diseases. Additionally, these data cannot accurately determine the false-negative test characteristic of dipstick urinalysis. This could have been overcome by combining our database with the database of the military general practitioners. However, this would have generated a substantial administrative burden due to European privacy legislation. We feel the effect of this shortcoming is minimal, as we have a good relationship with our diving and submarine community, but it cannot be entirely ruled out.

Lastly, the number of 'unfit' divers in our population is very low compared to other studies. This is most likely due to the aforementioned option to withdraw from the assessment, resulting in an 'other' result. It is, therefore, perhaps best to regard 'other' as 'unfit' when interpreting these results. The three candidates in the group with positive test results on urinalysis that were in the 'other' category would have been 'unfit' for other reasons (two cases with an insufficient pulmonary function test, one case was not physically fit enough and scored too low on the exercise ergometry). Therefore, we feel this has not affected the interpretation or conclusion of the present study.

Conclusions

This retrospective study covering 10 years of data on dive medical assessments in military divers, submariners, and hyperbaric personnel showed an incidence of 0.8% of positive test results on urinalysis. Almost half of the cases could be cleared right away; the other half were regarded temporarily unfit for diving and generally required retesting or additional investigations, after which they were deemed fit to dive. Therefore, routinely assessing urine in asymptomatic healthy candidates is neither cost-effective nor clinically useful. The authors advise taking a thorough history for fitness to dive assessments and only analysing urine when a clinical indication is present.

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