Limiting Anthropometric Criteria for Medical Staff when Undertaking Aeromedical Operations in Rotary Wing Aircraft

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ABSTRACT

New South Wales (NSW) Ambulance Aeromedical Operations Division (AOD) is standardising helicopter types with increased reliance on the Leonardo AW139. The AW139 has specified limits for the height and weight of medical crew (doctors and paramedics) when harnessed to the front and rear anchor points within the helicopter, and specified limits for the combined weight of medical crew, patients and equipment during stretcher winching operations. An anthropometric analysis was conducted to provide guidance on the height and weight ranges applicable to crew members based on the limitations of three system components: cabin seated height, hardpoint limit and winch limits (during stretcher winching operations). It was determined that seated height is a key dimension that would limit crew ability to interact with the cabin, this was at 935mm with helmet, clothing and seat depression correction factors included. This corresponds to 91st%ile Australian male seated height and 99th%ile Australian female seated height. Therefore, most of the Australian population should be able to sit in the cabin based on this dimension. In the analysis, hardpoint and winch weight limitations do not exclude a significant portion of the Australian population (e.g., 3% of males with a hardpoint weight limit of 130kg). However, it was found that the higher the weight of the crew member, the lower the weight of the patient that can be safely winched, especially when winching occurs below 0°C. Tables were developed to illustrate the effect of the limitations of system components on crew weight. It is concluded that the interaction of the analysed system component with patient weight would be key in understanding applicable crew height and weight ranges. It is recommended that seated height be formalised as an initial guidance, followed by ensuring crew understand the interrelationship between the safe working load on the hardpoint, weight on the winch and patient weight. This presented a good opportunity for NSW Ambulance AOD to integrate calculations of system component limits into formalised training. The operational context and general health/fitness to fly would also need to be considered for effective aeromedical operations.

KEYWORDS

Anthropometry, Aeromedical, Helicopter Operations

Introduction

NSW Ambulance Aeromedical Operations Division (AOD) is standardising helicopter types with increased reliance on the Leonardo AW139. The AW139 has specified limits for the height and weight of medical crew (doctors and paramedics) when harnessed to the front and rear anchor points within the helicopter, and specified limits for the combined weight of medical crew, patients and equipment during stretcher winching operations. NSW Ambulance AOD requested an anthropometric analysis of the suitability of the existing limits, engineering constraints associated

with AW139 cabin fit-out, and acceptable anthropometric limits for medical crew (specifically for height and weight).

Constraints related to the cabin fit-out, winch limit, hardpoint limit and equipment load have implications on the height and weight associated with operational staff, as well as the weight of patients that can be safely winched on a stretcher. Based on the flight manual supplement for the harness hardpoint attachment (Ref: 5R-4796-FMS Issue 1), Airworthiness Directive for the hoist/winch (Ref: AD No:2015-0226R4) and internal AOD discussions, system component dimensional limitations were derived as a basis for analysis along with anthropometric tables for the Australian population.

The aims of this study were to provide NSW Ambulance AOD with objective anthropometric guidance on crew weight and height to facilitate aeromedical operations through the provision of:

- Guidance on the height and weight ranges applicable for crew members based on cabin seating constraints, system components (winch, hardpoint) and PPE/equipment,
- Guidance on allowed weight of patients (particularly bariatrics) based on anthropometric analysis of crew weights, and
- Identification of additional investigations and recommendations which could be conducted or considered by NSW Ambulance AOD.

Method

The human factors specialists first engaged with AOD staff to understand the context and space for aeromedical stretcher winching operations. Following this, documentation was reviewed regarding current operational limits and calculations undertaken by crew for stretcher winching operations. Based on the documentation provided and observations, the specialists reviewed the current specified weight limits against anthropometric data and first principles. Seated crew height was chosen as a determinant of the range of the population that could safely sit in the cabin without impact on the cab deckhead. Seated crew height could then be used to provide a weight range indication typical for a person of the associated height.

An anthropometric calculation for crew weight was conducted with consideration of winch limits (above and below 0 degrees Celsius), PPE, equipment, and patient weights. Crew weights examined were based on the guidance range provided (105-115kg) by AOD as this could indicate how much of the population would be excluded based on current staff anthropometry. Crew body weight was also assessed as a co-variable with the hardpoint weight limit. This calculation would show what percentage of the population would be able to safely use the hardpoint.

From the above calculations it was possible to determine which segments of the Australian population would be able to undertake aeromedical operations based on their height and weight. All calculations were based on Australian population anthropometric data from PeopleSize (2008). The following system component dimensional limits were used for the analysis (Table 1).

Table 1: System Component Limitations used for anthropometric analysis (*Airworthiness data or otherwise supplied estimates)

System Component	Dimension Limits	
Seat reference point to deckhead with seat fully depressed	980mm (includes 30mm	
	seat cushion compression)	
Wander lead/Hardpoint	130kg*	
Personal Protective Equipment (PPE)	10kg	
Winch (above 0 degrees Celsius)	249kg*	
Winch (below 0 degrees Celsius)	227kg*	
Flight helmet correction factor	40mm	
Equipment weight (oxygen cylinders, medical valise etc.)	32kg	
Clothing correction factor	5mm	

Design and Operations familiarisation

Two Human Factors specialists visited Bankstown airport to meet with SMEs for a demonstration of harnessing and stretcher winching operations and to understand current limits, operational constraints, and rules for aeromedical operations. A typical rescue crew would consist of pilot, aircrewman, paramedic and doctors. Usually, the medic sits in the after seat, facing forward and the aircrewman sits in the forward seat facing aft. The aircrewman may move to the after seat when working on a patient.

Seating Height/Weight Calculation

Seated height was determined based on the distance between the seat reference point with compressed seat cushion (30mm compression) to a deckhead height of 980mm. A slumped seating position (40mm) was used as the basis of anthropometric height calculations as this more relaxed posture is more commonly utilised than an upright seated position. The anthropometric dimension of popliteal height floor to top of the head) was used for seated height.

Although there is a general correlation between height and weight, build can have an impact on ergonomic and functional capability. A person who is at the seated height of 935mm may be overweight or underweight according to their build. Similarly, a person who has a lower seated height may be overweight or underweight. General health, wellbeing and build are other factors that could be considered when considering the ideal weight for AOD operations.

Winch Weight Calculation

Winch weight calculations were based on airworthiness data relating to the use of equipment under ambient environmental conditions (above or below freezing) (Ref: AD No: 2015-0226R4) and is relevant to stretcher winching operations. The winch weight calculation also considers estimated PPE, equipment weight and a recommended crew weight ranging from 105 kg to 115kg (inclusive). When above 0 degrees Celsius, the winch weight limit is 249kg, when below 0 degrees Celsius, the winch weight limit is 227kg (Ref: ADNo:2015-0226R4). Assumptions are made for PPE weight (10kg) and equipment weight (32kg).

Constraints

Due to considerable variance associated with aircraft movement it was not possible to factor this in. Secondly, an assumption was made that whilst seated the doctor would be strapped in which would limit vertical movements and accelerations. Detailed task analysis was out of scope for this assessment; however, the doctor would likely remain seated unless required to lean across the patient from their seat.

Results

Anthropometric Analysis

It was determined that the key limiting anthropometric factor associated with aeromedical operations would be height. Crew who exceed the seated height cabin constraints would not be able to conduct tasks comfortably, safely, or ergonomically within the AW139, independent of weight considerations.

Seating

Based on a clothing correction factor of 5mm, helmet correction factor of 40mm (mean estimate provided by NSW Ambulance AOD) the total available space for a seated crew member would be 935mm. In a slumped seated position, this corresponds to 91st %ile Australian male height and 99th %ile female height, which is illustrated in Table 2. The calculation for the maximum height of a crew member is based on cabin height restrictions. This means that the cabin height would exclude approximately 9% of the Australian male population based on seated height. Effectively, seated height is not a limiting factor for Australian females.

Table 2: Percentile of Australian population that will fit into AW139 cabin space (980mm) based on slumped seated height.

Gender	%ile seated height with helmet and clothing correction	%ile seated height with normal clothing	%ile weight (kg)
Male	91 st	99 th	91st %ile: 104kg 99th %ile: 130kg
Female	99 th	99 th	99th %ile: 113kg

There is a correlation between height and weight as those with a taller stature are generally likely to weigh more than someone with a similar build and shorter stature. Figure 1 shows the weight associated with the %ile seated heights of both Australian males and females. An Australian male at 91st %ile seated height corresponds to a weight of 104kg and an Australian female at 99th %ile seated height corresponds to weight of 113kg.

Hardpoint

Based on the airworthiness weight limit of 130kg, the limiting factor for body weight is the 98th %ile for Australian males. It is not a limiting factor for Australian females. The inclusion of PPE does not significantly change the numbers of crew excluded based on the hardpoint limit. However, at the top weight it is possible even low levels of acceleration would likely impact the safe working load of the hard point. The calculation is based on static weight only and does not take into consideration the effects on mass due to acceleration or movements from the hardpoint.

Figure 1 shows that as percentile body weight increases, aircrew are more likely to exceed the hardpoint weight limit of 130kg. However, this only occurs at the 98th %ile for males, meaning that most of the Australian population is unlikely to exceed the hardpoint limit. The red colouring indicates on the graph at what percentile and body weight the safe working load on the hard point is exceeded.



Figure 1: The relationship between the crew body weight/body weight percentile and hardpoint limit.

Rescue Winch

The winch working load is 227kg for operation below 0 degrees Celsius and 249kg for operation above 0 degrees Celsius (AD No: 2015-0226R4). The recommended weight of 105 - 115 for crew members was suggested for AOD and is the range of crew weight on which this section of the analysis was conducted. Figure 2 below shows that as the weight of the crew member carrying PPE and equipment increases, the weight of the patient must decrease to be under winch working load limits. PPE and equipment increase base crew weight by 42kg. The red shaded area indicates where the patient is at or above 100kg and may require different operating procedures to accommodate for the weight of the patient and/or potential bariatric patients.



Figure 2: The relationship between crew weight and patient weight based on stretcher winch, PPE, and equipment limits.

Generally, the heavier the aircrewman the lighter the patient that can be carried within the winch limit. Within the range suggested by NSW Ambulance AOD, at 105kg the maximum patient weight would be 102kg above 0 degrees Celsius. This is equivalent to 89th %ile Australian male and 97th %ile female, therefore 11% of the Australian male population and 3% of the female Australian female population would be excluded. In contrast, for operations below 0 degrees Celsius and if the crew weight were 105kg, the maximum weight of the patient could be 80kg, which corresponds to 35th %ile of the Australian male population, 77th %ile Australian female population thereby excluding 65% of the Australian male population and 23% of the Australian female population.

An important consideration is the transport of bariatric patients because of their levels of obesity. They should be considered as a special case in any rescue operation. What may be considered 'bariatric' are BMI measurements of 35 and above (The Royal Australian College of General Practitioners, 2016). It should be noted that NSW AOD make bariatric preparations for patients at or above 100kg.

Analysis of relationship between components

To determine limiting factors associated with the analysis above, the first criterion must be - can an aircrewman or medic meet the seated height requirement? It follows that once in the aircraft, is it safe to hook onto the hardpoint and finally be supported by the winch? See the flow diagram below (Figure 3). Note that the percentiles indicate the percentage of Australian male or female population that would be included on that dimension, e.g., 91st %ile male seated height, means that 91% of Australian males would likely be able to sit in the cabin.



Figure 3: Relationship between components

Discussion

The analysis has demonstrated that there are three limiting dimensions: seated height, weight on the hardpoint and weight on the winch. These subsystem variables interact significantly and must be considered at the system level. The ideal height and weight for crew would be based on the limiting dimensions and operational context.

The ideal crew height can be determined by the cabin limits (i.e., under 935mm seated height), however, the ideal crew weight is dependent on several factors which require consideration of the operational context. Some foundational factors discussed in this report include the weight of PPE and equipment, and whether the patient will be stretcher winched above or below 0°C. Other contextual limitations will also need to be considered. It would be beneficial as part of new induction training (if not already formalised) to provide opportunities to practice calculations relating to the system components (e.g., winch, equipment, and patient weights).

The data provide guidance in the assessment of height and weight requirements for medics and aircrew responsible for patient care and handling during aeromedical operations. Whilst there is a correlation with height and weight, i.e., the taller the person, the more they will weigh, this is not applicable to all cases due to the range and variability of body size and build (e.g., muscle mass). Bariatric patients would require a case-by-case assessment and acknowledgement of current operational procedures relating to patients over 100kg. The conclusions drawn should also bear in mind any medical or other requirements regarding staff obesity or fitness to fly.

It is extremely difficult to make assumptions regarding the airworthiness elements and aircraft performance factors in relation to the ergonomics analysis described here and these will have a significant bearing on this guidance. Sudden changes in aircraft attitude in pitch or roll could generate significant accelerations on someone's body leading to a strain on the hard point. Obviously, someone of larger body mass would be more at risk.

Overall, among the unknown variables, the interaction with patient weight is significant in determining safe crew weight during stretcher winching operations. Once all the known variables (PPE, equipment, crew weight) are calculated, it is possible to estimate the weight of a patient that can be safely carried. Conversely, if patient weight is known, then the other known variables (crew weight, equipment) can be adjusted to provide a relatively safe solution for the operation.

Self-selection plays a large part in recruitment for aeromedical operations since they are inherently hazardous. This issue could further reduce the pool from which medics are drawn. This could impact operational staffing if further restrictions were placed on recruitment criteria. Key conclusions are:

- Primary criterion for medics and aircrew is seated height and this should be formalised, based on aircraft type.
- Secondary criteria are meeting the safe working load on the hardpoint and weight on the winch. These criteria are inter-related and must be considered together when determining safe maximum patient weight.
- Bariatric patients (e.g., those with BMI >35) must be assessed on a case-by-case basis due to winch limits. It is acknowledged through verbal discussions with AOD SMEs, different operational procedures are considered for patients from 100kg.
- These findings must also consider the wellbeing of aircrew and medics in terms of their weight, general health, and fitness to fly. This may include general medical health requirements and measurement of body mass index or hip to waist ratio. It is recommended that management implement or enhance policies to support the continued health and fitness of AOD crew members.

- The hardpoint safe working load should be further assessed by Airworthiness engineers to understand the implications relating to dynamic movement of the AW139 and its interaction with crew weight. This also applies to the winch and stretcher winching operations.
- It is recommended that aircrew be provided formalised training (if not currently undertaken) to make assessments of weight calculations based on known limits (i.e., crew weight, PPE etc). Practiced calculations will help facilitate decision making during stressful rescue scenarios undertaken by crew.
- In determining the ideal height and weight for crew members, judgement needs to be made of the frequency and type of operations and how they may impact the safe behaviours and musculo-skeletal health of crew members.
- Functional assessments, lessons learnt from previous helicopter upgrades, MSD data, completed risk assessments, incident data and detailed specifications of PPE are all sources of data which should be utilised to inform potential areas that could be investigated for improvement of ergonomic operations beyond consideration of height and weight.

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