CONTENT VALIDITY OF LEVEL TWO OF THE ROYAL AIR FORCE AIRCREW CONDITIONING PROGRAMME

Ellen Slungaard, MSc[1,2], Nicholas D.C. Green, PhD[1], Di J. Newham, PhD[2] & Stephen D.R. Harridge, PhD[2]

Affiliations:

[1] RAF Centre of Aviation Medicine, RAF Henlow, Bedfordshire, UK

[2] Centre of Human and Aerospace Physiological Sciences, Faculty of Life Sciences and Medicine, King's College London, UK

Corresponding Author:

Squadron Leader Ellen Slungaard, RAF Centre of Aviation Medicine, RAF Henlow, Bedfordshire, SG16 6DN, UK

Ellen.slungaard421@mod.uk

Manuscript Published Reference:

Slungaard E, Green NDC, Newham DJ, Harridge SDR. Content Validity of Level Two of the Royal Air Force Aircrew Conditioning Programme. *Aerosp Med Hum Perform.* 2018; **89**(10):896–904.

Suggested Short Title:

Validity of RAF ACP

ABSTRACT

INTRODUCTION: The prevalence of flight-related neck pain in all Royal Air Force (RAF) aircrew is 66% and 70% in UK fast-jet aircrew. The RAF Aircrew Conditioning Programme (ACP) has been designed to enhance pilot performance through reducing fatigue and strain injuries, particularly to the neck. Content validity of the ACP was assessed to determine the appropriateness for delivery to aircrew. **METHODS**: Six international medical experts reviewed level two of the ACP, which is delivered to student aircrew who have completed basic instruction in cervical spine stability, core stability and initial technique instruction for strength training. Content validity on overall exercise approach (5 items) and specific exercise session (24 items) was rated on a 4-point Likert-type ordinal scale for *relevance* and *simplicity*. Four reviewers had experience of delivering an exercise programme to aircrew. The item-content validity index (I-CVI) was the proportion of experts rating an item/exercise as acceptable (score 3-4) while protocol-CVI was the average I-CVI across items. **RESULTS**: Twenty of the suggested exercise sessions reached an excellent I-CVI (1.00) for *relevance* (4 reached acceptable I-CVI (0.83)), and 21 reached an excellent I-CVI (1.00) for *simplicity* (3 reached acceptable I-CVI (0.83)). Protocol-CVI for the ACP was excellent for *relevance* (0.90) and good for *simplicity* (0.83). The need for sufficient supervision during the exercises was recommended for safe exercise execution and to maintain adherence. **CONCLUSION**: The ACP demonstrated excellent relevance for the target population. The aircrew require additional supervision with the more complex neck exercises to enhance simplicity with the ACP.

KEY WORDS

Aircrew, exercise, acceleration, neck pain

INTRODUCTION

Concern over the ability of aviators to tolerate the considerable +Gz stressors of the modern high-performance aviation environment has grown in recent years[4]. There are direct and indirect consequences of +Gz stress. Direct consequences include loss of peripheral visual fields, visual greyout or blackout, and loss of consciousness. Indirect consequences include fatigue and subsequent loss of performance, and strain injuries – specifically to the neck[4]. Both of these consequences may have a broader effect on operational performance, affecting the capacity to manage +Gz stresses, complete missions and remain injury free.

Neck pain within military pilots is recognised as a challenging problem in modern air forces, with an estimated one-year prevalence in helicopter pilots approaching 50%[1]. Most injuries reported among fast-jet aircrew are described as strain of the neck muscles, with occasional neck pain and stiffness, related to frequent exposure to high +Gz forces in high performance jet aircraft[2]. The prevalence of flight-related neck pain in all Royal Air Force (RAF) aircrew is 66%[22] with 70% of UK fast-jet aircrew reporting flight-related neck pain[22].

Operating in a high +Gz environment is physiologically demanding, particularly if executing the anti-G straining manoeuvres (AGSM) which involves co-ordinated, sustained lower body and abdominal muscle contractions and cyclic 'Valsalva like' breathing manoeuvres[6]. Muscle strength and fatigue, and aerobic fitness are therefore likely to have a key role in G-tolerance[4]. An inability to perform an effective AGSM can result in G-induced loss of consciousness (G-LOC) or almost loss of consciousness (A-LOC).

The United States Air Force (USAF) developed the Fighter Aircrew Conditioning Test (FACT) as part of the G-Risk Indicator Management (GRIM) Program to enhance combat ability. The FACT contains 8 exercise events divided into strength and endurance categories; however a programme review failed to validate the overall preventative capability for G-LOC[5]. To counter the effects of prolonged exposure to microgravity, astronauts undergo a rigorous inflight exercise countermeasure programme on the International Space Station (ISS) and a post flight reconditioning programme on return[14]. A coordinated training programme focusing on neck muscle

control, with low load exercises to enhance the coordination of the cervical musculature has been suggested for military aircrew[17].

The RAF Aircrew Conditioning Programme (ACP) has been developed by the lead author (ES) following recommendations from a survey investigating the incidence of G-LOC and A-LOC in the RAF[19]. The ACP is a structured and progressive exercise programme which aims to enhance aircrew performance through improvements in the ability to repeatedly perform an effective AGSM and reduce strain injuries to the neck, enhancing the ability to lookout of the cockpit.

The ACP has been designed as a preventative strategy for aircrew with no current injury, delivered to qualified aircrew and all student aircrew within the Flying Training (FT) pipeline, regardless of phase of training or aircraft type. It has been designed to become more role and platform specific as student aircrew progress through the FT pipeline, with minimum standards recommended for each stage. As part of the ACP, aircrew receive a period of supervised instruction in small groups (maximum of 8 aircrew per instructor) in all the exercises enabling them to continue their individualised conditioning programme independently.

The aim of this study was to assess the content validity of level 2 of the ACP for appropriateness for delivery to an aircrew population, and for delivery by a team of trained physical training instructors (PTIs) and physiotherapists.

METHOD

The ACP should be delivered by trained PTIs who complete a 5 day instruction course covering all components of the ACP, and a physiotherapist who completes a one day course covering the specialist areas of assessment which includes neck muscle strength and range of motion. The physiotherapist also delivers a presentation at the start of each stage of FT which provides an overview of the ACP and the reasons behind its use. Supervised ACP sessions are delivered during mandated periods during both the ground school and flying phases of training. The hourly sessions are delivered twice a week for 12 weeks with aircrew required to attend all the supervised sessions.

The ACP consists of 4 main components; i) whole body flexibility and mobility, ii) cardiovascular fitness, iii) stability and motor control of the neck, shoulder girdle and trunk, and iv) strengthening exercises of the neck, back, abdominal and leg muscles. Each exercise session consists of a combination of those components (Fig. 1). At all times aircrew are encouraged to maintain a neutral cervical spine position through activation of the deep segmental stabilisers, with the load increasing only if a neutral position is maintained (Fig. 2). Visual and verbal feedback is provided by the PTI/physiotherapist during the exercises.

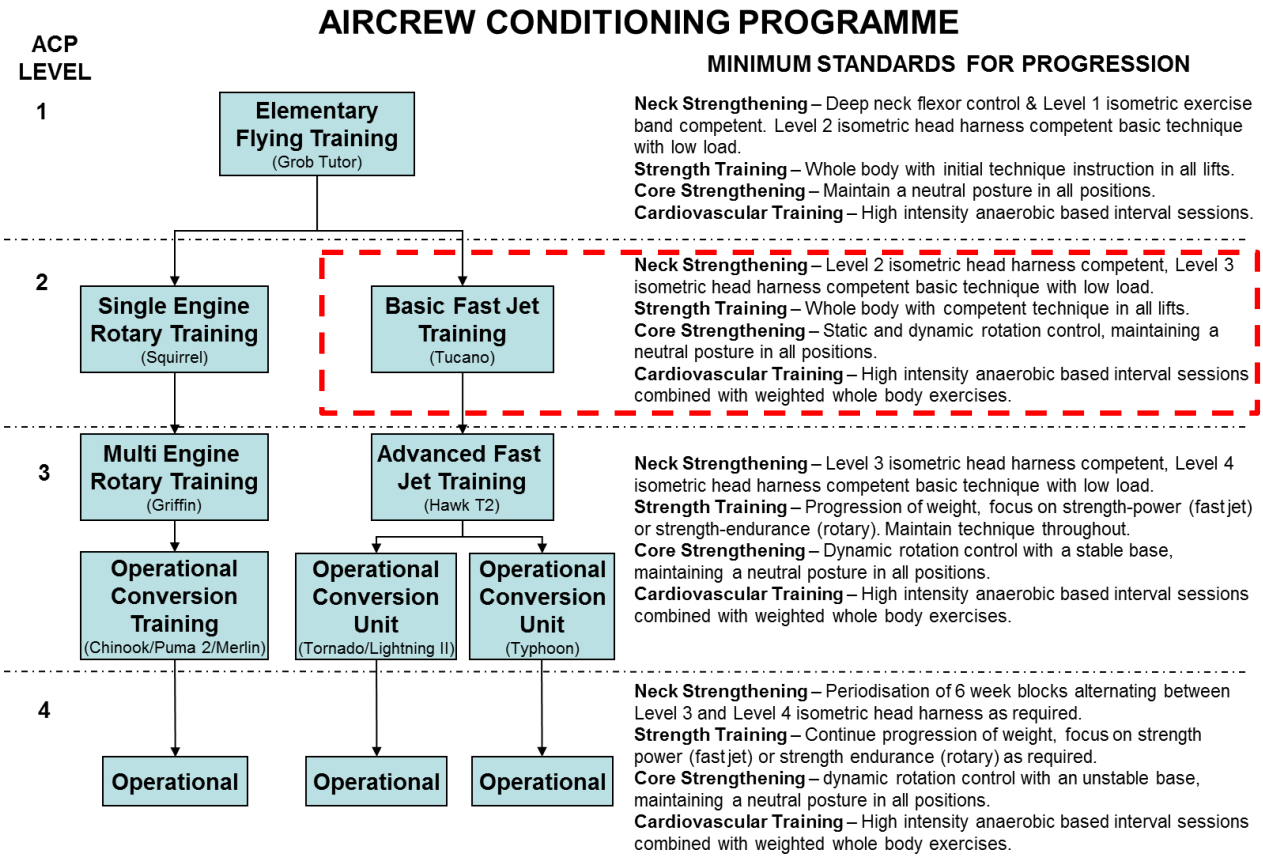

Fig. 1 Aircrew Conditioning Programme (ACP) Delivery Flowchart. ACP Level 2 (area with dashed box around) was reviewed by the panel of experts. Whole body flexibility and mobility exercises which include general stretching exercises and use of a foam roller to the main muscle groups are advised for all ACP levels. The aim of the stability and motor control exercises is to maintain a neutral cervical spine posture under load in all positions and develop rotational core control in a seated position. The weight is only increased with the strengthening exercises once initial technique is appropriate and safe, and the technique must be maintained throughout the movement as the load is increased. All neck exercises are performed isometrically in a spinal neutral position with low loads of 1-4kg.

Fig. 2 Isometric neck exercises included in the Aircrew Conditioning Programme (ACP) showing the progression between each level from level 1 to 4.

The ACP underwent a two-stage process to assess content validity; a development stage and a judgement-quantification stage[10]. Stage I consisted of a development stage with delivery at a number of RAF flying stations over a period of two years. At the end of this period, the ACP was reviewed and adjusted as a result of feedback received by all individuals involved (aircrew, PTIs and physiotherapists) in conjunction with the lead author (ES), which lead to the final ACP which was then assessed for Stage II (judgement-quantification) of content validation.

Level 2 of the ACP (Fig. 1) was rated as it provides the basis for continued continuity and progression. This level was designed to be delivered to student aircrew at the second stage of flying training who had received basic instruction in cervical spine stabilisation exercises, core stability, and initial technique instruction for strength training exercises by a qualified PTI for a minimum of 12 sessions over a 6 week period. An overview of ACP Level 2 (Table I) and a copy of the ACP Aircrew Aide-Memoire which was a booklet containing a description with pictures of all the

exercises were provided to the expert reviewers. Levels 3 and 4 provide further progression of all the components with increased emphasis on whole body strengthening for fast-jet aircrew and rotational core control and flexibility for rotary aircrew.

Week	Session	Aircrew Conditioning Programme Components	
1	1	Deep neck flexor control and Level 1 isometric neck loading with elastic exercise band	1 Rep Max Test - Double leg press, flat barbell bench press, timed plank to failure
	2	Review deep neck flexor control and Level 1 isometric neck loading with elastic exercise band	Anaerobic Session – interval rowing
2	3	Level 2A isometric neck loading with head harness (walking based exercises)	Strength Session
	4	Level 2A isometric neck loading with head harness (walking based exercises)	Anaerobic Session – running sprints
3	5	Level 2B isometric neck loading with head harness (kneeling based exercises)	Core Stability Session
	6	Level 2B isometric neck loading with head harness (kneeling based exercises)	Anaerobic Session – interval rowing and kettle bell
4	7	Level 2A isometric neck loading with head harness (walking based exercises)	Core Stability Session
	8	Strength Session	Level 2A isometric neck loading with head harness (walking based exercises)
5	9	Level 2B isometric neck loading with head harness (kneeling based exercises)	Strength Session
	10	Anaerobic Session – whole body weights	Level 2B isometric neck loading with head harness (kneeling based exercises)
6	11	Introduce Level 3A isometric neck loading with head harness (whole body compound movements)	Anaerobic Session – interval rowing
	12	Level 3A isometric neck loading with head harness (whole body compound movements)	Core stability
7	13	Introduce Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)	Strength Session
	14	Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)	Strength Session
8	15	Level 3A isometric neck loading with head harness (whole body compound movements)	Anaerobic Session – spinning bike intervals
	16	Level 3A isometric neck loading with head harness (whole body compound movements)	Anaerobic Session – whole body weights with sprints
9	17	Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)	Strength Session
	18	Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)	Strength Session
10	19	Anaerobic Session – interval sprints	Level 3A isometric neck loading with head harness (whole body compound movements)
	20	Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)	Anaerobic Session – interval rowing
11	21	Strength Session	Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)
	22	Level 3A isometric neck loading with head harness (whole body compound movements)	Anaerobic Session – whole body weights with sprints
12	23	Level 3A isometric neck loading with head harness (whole body compound movements)	Strength Session
	24	Level 3B isometric neck loading with head harness (sitting on exercise ball with arm movements)	Anaerobic Session – whole body weights with sprints

Table I. Overview of Aircrew Conditioning Programme Level 2. Each session is supervised, lasting for one hour and is spilt into two parts.

A panel of 6 international independent experts were chosen for their expertise and availability and approached to participate. All had experience of either designing or delivering an exercise programme to aircrew, and all had doctoral degrees (4 physiotherapists, one physician and one kinesiologist). None were involved in the initial development and piloting of the ACP. All gave written informed consent before taking part, and confidentiality and the voluntary nature of the study were stressed.

Experts were asked to rate each item (individual exercise session or entire ACP) in terms of relevance and simplicity using a 4-point ordinal Likert rating scale[10] as follows; 1 – not relevant/not simple, 2 – somewhat relevant/exercise need some revision, 3 – quite relevant/clear but needs minor revision, 4 – highly relevant/very simple[21]. 'Not relevant' indicated that the individual exercise session/ACP was believed to be either of no benefit (or give no positive effects) in terms of treatment or prevention of spinal pain, or was not applicable to aircrew[13]. 'Not simple' indicated that the individual exercise session/ACP was believed to be too difficult for the aircrew to accomplish (including home exercising), or for the physiotherapist/PTI to supervise the individual exercise session/ACP (including individual adjustment and progression)[21]. Grades 3 and 4 were considered acceptable[10]. A 4-point scale was used to avoid having a neutral and ambivalent midpoint.

Results were recorded in a standardised table. Item content validity index (I-CVI) was calculated for each item (24 exercise sessions) as the number of experts giving a rating of acceptable (score 3 or 4), divided by the total number of experts[15]. The criterion for item acceptability that incorporates the standard error of the proportion has been recommended as ≥ 0.83 for 6 experts[10]. The I-CVI was then used to provide guidance with revising, deleting or substituting items within each ACP exercise session.

The scale-level CVI (S-CVI) was calculated based on the ratings of relevance and simplicity by the 6 experts, using the averaging approach (S-CVI/Ave)[16]. It was calculated as the average proportion of items rated as 3 or 4 across the various experts. The lower limit of acceptability for S-CVI/Ave has been recommended as ≥ 0.90 for a scale to be judged as having excellent content validity[16].

Protocol-CVI was also calculated for the overall ACP using the same 4-point rating criterion as I-CVI. Experts were asked to rate the ACP against 5 questions; i) is the progression of exercises relevant and simple? ii) is the weekly supervision including instruction and manual guidance relevant and simple? iii) should the assigned exercises be conducted twice weekly? iv) can participants perform the ACP independently of any instructors, but within the gym? and v) is the aide-memoire with pictures illustrating the exercises given to the participants relevant and simple? The protocol-CVI was calculated for each question as the number of experts giving a rating of acceptable (score 3 or 4), divided by the total number of experts. For qualitative feedback the experts were also asked if any exercises should be either deleted or added to the protocol, with reasoning behind the decision.

RESULTS

Item Content Validity Index (I-CVI)

The I-CVI of the individual exercise sessions was rated an excellent score for both relevance and simplicity for the majority of the exercise sessions. The relevance of 20 of the suggested exercise sessions reached an excellent I-CVI (1.00); with 4 items reaching acceptable I-CVI (0.83). For simplicity, 21 of 24 suggested exercise sessions reached an excellent I-CVI (1.00); the other three exercise sessions reaching acceptable I-CVI (0.83) (Table II).

Item	Number of Experts in Agreement	Item-CVI for Relevance	Item	Number of Experts in Agreement	Item-CVI for Simplicity
1	5	0.83	1	5	0.83
2	5	0.83	2	5	0.83
3	5	0.83	3	6	1
4	5	0.83	4	6	1
5	6	1	5	6	1
6	6	1	6	6	1
7	6	1	7	6	1
8	6	1	8	6	1
9	6	1	9	6	1
10	6	1	10	6	1
11	6	1	11	5	0.83
12	6	1	12	6	1
13	6	1	13	6	1
14	6	1	14	6	1
15	6	1	15	6	1
16	6	1	16	6	1
17	6	1	17	6	1
18	6	1	18	6	1
19	6	1	19	6	1
20	6	1	20	6	1
21	6	1	21	6	1
22	6	1	22	6	1
23	6	1	23	6	1
24	6	1	24	6	1
S-CVI/Ave for Relevance		0.97	**S-CVI/Ave for Simplicity**		0.98

Table II. Item content validity index (I-CVI) rating results for relevance and simplicity for each item (24 exercise sessions) calculated as the number of experts giving a rating of acceptable (score 3 or 4), divided by the total number of experts (n = 6)[15]. The criterion for item acceptability that incorporates the standard error of the proportion has been recommended as ≥ 0.83 for 6 experts[10]. Scale-level content validity index (S-CVI) was calculated based on the ratings of relevance and simplicity by the 6 experts, using the averaging approach (S-CVI/Ave). The lower limit of acceptability for S-CVI/Ave has been recommended as ≥ 0.90 for a scale to be judged as having excellent content validity[16].

Four exercise sessions (1 - 4) were rated acceptable for relevance. These sessions included a review of exercises to activate the deep neck flexor muscles, progression onto activation of the global neck stabilising muscles, review of technique when performing global strength exercises e.g. squat and bench press, and some anaerobic interval sessions. One expert felt that the deep neck flexor exercises required greater supervision, with care not to progress the exercises too soon but if this was addressed the relevance and simplicity would be rated higher.

Exercise sessions 1, 2 and 11 were rated acceptable for simplicity. Session 11 (Table I) involves progression of the neck exercises from level 2 (basic isometric neck exercises with a head harness) to level 3 (isometric neck exercises with a head harness combined with more complex movements of both the upper and lower limb), all whilst maintaining a neutral neck position under a low load. One expert liked the progression to the more complex exercise, but noted that these may be too challenging for some aircrew, with care required on progression.

Scale-Level Content Validity Index

The scale-level CVI (S-CVI/Ave) calculated as the mean I-CVI for all 6 experts across the suggested 24 exercise sessions was rated excellent for both relevance and simplicity (0.97 and 0.98 respectively) (Table II).

Protocol Content Validity Index

The protocol-CVI for the ACP was rated good for relevance (0.90) and acceptable for simplicity (0.83) (Fig. 3). A protocol-CVI of ≥ 0.90 has been recommended for a scale to have excellent content validity and 0.80-0.89 to be rated acceptable[15]. The ACP was rated excellent for relevance for the following; progression of exercises, weekly supervision and quality of the aide-memoire. It was rated acceptable for relevance for; ‘should the assigned exercise be conducted twice weekly?’, and fair for; ‘can participants perform the ACP independently of any instructors, but within the gym?’ One of the experts recommended that the exercises should be conducted on a more frequent basis and two felt that the aircrew should be closely monitored to encourage maximum adherence to the programme. The ACP was rated good (0.83) for simplicity for all the questions.

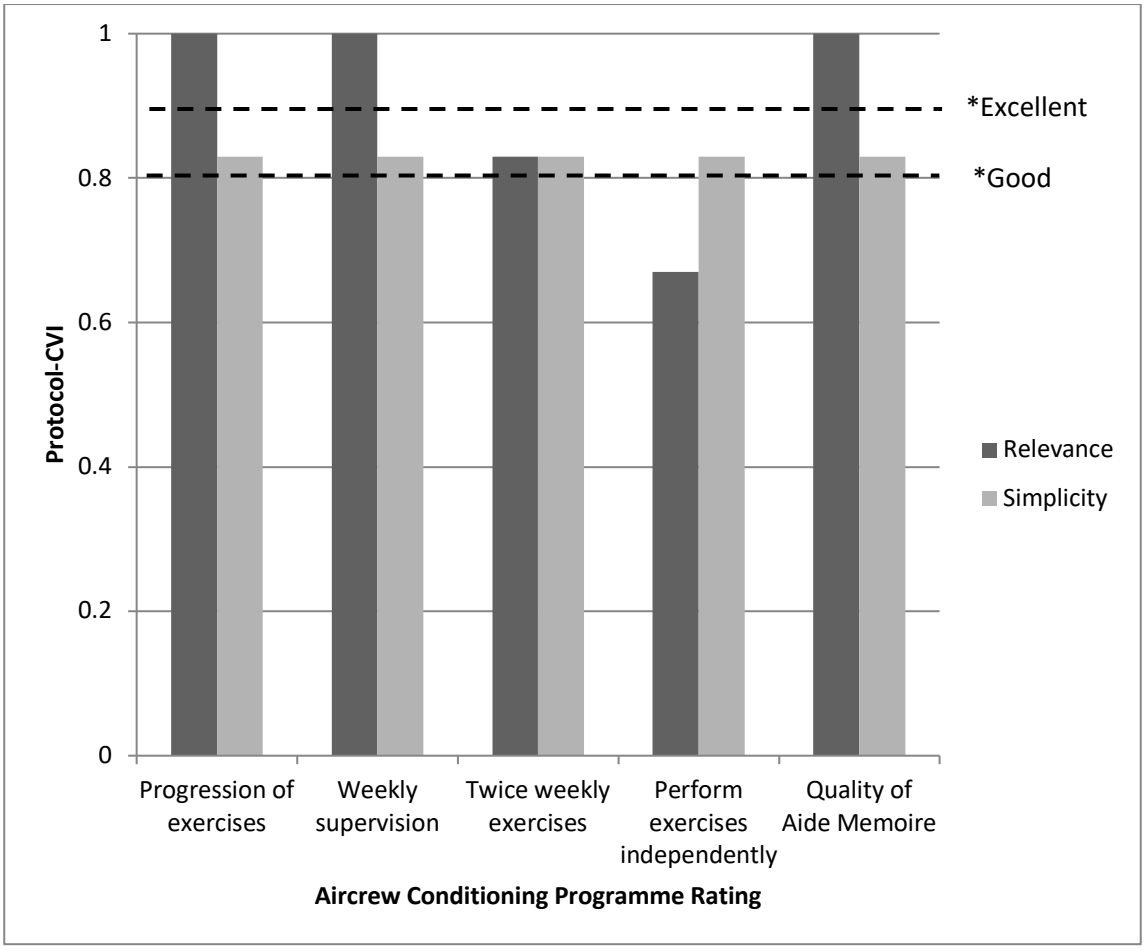

Fig. 3 Protocol content validity index (protocol-CVI) was calculated for the overall Aircrew Conditioning Programme (ACP) (Level 2). Experts rated the ACP against 5 questions; i) is the progression of exercises relevant and simple? ii) is the weekly supervision including instruction and manual guidance relevant and simple? iii) should the assigned exercises be conducted twice weekly? iv) can participants perform the ACP independently of any instructors, but within the gym? v) is the aide-memoire with pictures illustrating the exercises given to the participants relevant and simple? The protocol-CVI was calculated for relevance and simplicity for each question as the number of experts giving a rating of acceptable (score 3 or 4), divided by the total number of experts. *Protocol-CVI was rated excellent (0.90) for relevance and good (0.83) for simplicity.

ACP Development

For completeness, the panel was also asked if any exercises should be deleted from or added to each individual exercise session or the overall ACP (Table III). Three experts did not feel that any exercises should be deleted from the ACP, with one stating that all the exercises were appropriate and would be beneficial. One expert did feel that some of the initial head harness neck exercises could be improved. Also, there were contrasting views between the remaining two experts regarding the inclusion of front squats over back squats, with one preferring front squats to be optional for the aircrew, and the other preferring front squats over back squats due to the tendency

for the load to be placed too high causing extreme forward position of the neck under load. A number of suggestions were made for additional exercises to be added to the ACP; pre-flight neck isometrics to compliment the dynamic neck stretches; a kettlebell session based around functional movement; fast and varied arm movements whilst maintaining a neutral neck position to increase dynamic control; more frequent core stability exercises; and controlled dynamic low load tasks. Care on progression and supervision of early deep neck flexor and core work was also recommended, although an expert did note that the ACP was very comprehensive.

Expert	Should any exercise(s) be deleted from the protocol?	Should any exercise(s) be added to the protocol?
1	Front squatting is questionable, it could be optional	Pre-flight neck isometrics (against hand) could compliment dynamic neck stretches.
2	Neck strengthening 2B seem unnecessary. Could there be an alternative progression as this seems difficult to grasp and appears to be not as functional as the rest of the programme.	Perhaps a kettlebell session based around functional movement.
3	No, all exercises seem relevant and well placed	Neck strengthening progression very much seems to be based on progressive weight loading, but fast and varied arm movements might also be relevant whilst maintaining neutral neck position. This might be functionally relevant and increase dynamic control. Care on early deep neck flexor and core work.
4	Overall looks a great programme. Really my main area would be looking at the neck and core, and these exercises do look great. Given the history of low back pain and the current recommendation for core exercise, would it be possible to make these more frequent in the programme?	Have you considered some controlled dynamic low load tasks?
5	Congratulation on putting together the Cadillac of exercise programmes. I do not have any specific comments – the exercises are all appropriate and would be beneficial.	My concerns relate to the level of detail and length of the programme. Aircrew may not fully adhere to the programme because of the volume and detail.
6	I'm not a huge fan of back squats generally because of the tendency for the load to be placed too high causing extreme forward positioning of the neck under load. Front squats are my preference because of this.	Very comprehensive program.

Table III. Suggestions by the panel of experts of which exercises should be deleted/added to the protocol (Aircrew Conditioning Programme).

DISCUSSION

The ACP demonstrated excellent content validity for the individual exercise sessions (I-CVI) and for the overall programme (protocol-CVI) in terms of relevance and simplicity for delivery to the aircrew population. Of the 24 exercise sessions, 20 were rated excellent (I-CVI 1.00) for relevance and 21 were rated excellent (I-CVI 1.00) for simplicity. The remaining exercise sessions were rated acceptable (I-CVI 0.83) for relevance and simplicity. S-CVI/Ave reached 0.97 for relevance and 0.98 for simplicity, and was higher than the recommended 0.90[15].

CVI is an index of interrater agreement that simply expresses the proportion of agreement, and agreement can be inflated by chance[15]. For Stage II, the judgement-quantification stage, a minimum of five experts has been recommended, providing sufficient control for chance agreement[10]. A criterion has also been developed for item acceptability that incorporates the standard error of the proportion[10], recommending that when there are 6 or more judges, the I-CVI should be no lower than 0.83 for the rating to be assessed content valid[10]. This allows for one 'not relevant' rating with six judges.

The ACP exercise sessions which were rated as acceptable for relevance to the aircrew were sessions 1-4, with three sessions (1, 2 and 11) scored as acceptable for simplicity. Sessions 1-4 involve a review of the basic neck exercises (level 1) which includes activation of the deep neck flexor muscles, progressing to the initial isometric neck exercises using a head harness attached to a weighted pulley system in a standing position. For all of these exercises, the aircrew are advised to maintain a neutral head posture. The panel commented that increased supervision was required for the aircrew during these early sessions, to ensure effective activation of the deep neck flexor muscles prior to progression with increased load and limb motions. Exercise session 11 involved progression of the neck exercises to more complex isometric loading of the neck in a neutral position in a standing and sitting position. These exercises combine low loading of the neck muscles with complex whole body movements with an emphasis on either strength-endurance (squat, lunge, trunk side bend) or strength-stability (sitting on an exercise ball maintaining a neutral spine whilst moving the upper limb with resistance) (Fig. 1). Again, the panel felt that as these were complex movements requiring a relatively high degree of skill, there should

be suitable supervision of the aircrew by the PTI/physiotherapist during this session. The ACP exercise sessions have now been adjusted to include greater supervision with the inclusion of an additional PTI during all the sessions highlighted.

The original design of the ACP was centred on a neck and shoulder exercise programme that had been shown to be effective in reducing neck pain in air force helicopter pilots[3], which involved physiotherapist supervised exercise sessions progressing from non-postural to postural load-situated exercises, moving largely from isolated low-load muscle exercises to synergy endurance-strength exercises[3]. The non-postural exercises incorporated activation of the cervical spine deep postural muscles and scapular muscles, progressing to activation of the same muscles in a sitting posture. The endurance-strength exercises involved dynamic shoulder retraction and dynamic neck rotation exercises using an elastic exercise band, maintaining activation of the deep cervical muscles throughout[3]. During the development phase of the ACP, this exercise programme was delivered to aircrew flying a high +Gz capable aircraft. Unfortunately, the feedback from the aircrew was that the exercises, whilst improving neck symptoms when sat in the office, made little or no difference to the neck pain reported during the +9 Gz air-combat sorties. As a result of this feedback, additional neck exercises were added to the ACP.

The neck exercise component of the ACP now follows a coordinated training programme with focus on activation of the deep segmental cervical stabilisers (deep neck flexor muscles) in a neutral standing position prior to the addition of limb motion and loading of the superficial prime movers. This follows the principles recommended by Ang et al[3] and Salmon et al[18] who both described an exercise programme for improving neck muscle function in helicopter aircrew with neck pain. Whole body motor control exercises are also advised for all ACP levels to improve movement quality and maintain posture[7].

Increased neck muscle strength has been suggested to protect and stabilise the head and neck during brief episodes of increased loading as a result of +Gz[2], and a targeted deep neck muscle training programme combined with neck and shoulder strength training proved effective in reducing neck pain in F-16 pilots[9]. Loading of the cervical muscles to 50% of the maximum voluntary isometric contraction has been shown to mimic the neck loads experienced during +5 Gz,

suggesting that fast-jet aircrew should strengthen their necks to withstand these loads during air-combat sorties[12].

As part of the ACP following effective activation of the deep neck flexor muscles, aircrew progress to isometric loading of the neck in a neutral position using a head harness attached to a weighted pulley system initially in a standing position, eventually progressing to a sitting position. These exercises are based on a progressive and supervised isometric neck strengthening program which reported a significant decrease in match-related cervical spine injuries in a men's professional rugby union team[11]. This exercise programme involved isometric loading of the neck in a neutral position using a head harness attached to a weighted pulley system cable into flexion, extension, lateral flexion and 45 degree neck flexion to the left and right. Players completed a 13 week strengthening phase followed by a 13 week maintenance phase with any asymmetries identified on baseline strength testing addressed. Variations of these exercises were added to the ACP but aircrew were not progressed to them until they had sufficient control of the deep cervical muscles (Fig. 2).

For protocol-CVI the experts rated the ACP for relevance and simplicity against a series of questions (Fig. 3). Four of the experts rated the ACP excellent for relevance for all of the questions. However, one commented that the exercises should be completed more frequently and two felt that the ACP required greater supervision particularly during the neck exercises and the control exercises. For simplicity 5 of the experts rated the ACP excellent for all the questions and one expert consistently rated the exercises as needing some revision to improve the simplicity. The expert commented that the ACP was too ambitious and preferred for the aircrew to concentrate on a few key exercises that could be implemented into their own training habits and completed more frequently.

The panel of experts were asked if any of the exercises should be either deleted from or added to the ACP, with reasons given (Table III). The majority of them commented that the exercises were relevant, appropriate and beneficial. There were mixed views regarding the inclusion of front squats over back squats but it was felt that with appropriate instruction both exercises were safe and appropriate for the aircrew.

A number of suggestions were made for inclusion into the ACP. Pre-flight neck exercises will now be added to the pre-flight stretching exercises. A kettlebell session based around functional movement patterns has also been added to the new ACP based on this study. As discussed earlier, all the experts recommended the need for sufficient supervision during the exercises both from a safe exercise execution and to maintain aircrew adherence to the ACP. This is in line with previous exercise programmes designed for aircrew[3,18] and astronauts[8], and an additional PTI will now supervise the highlighted sessions. Whilst the quality of the supervision of the ACP exercise sessions has not been directly measured, it is noted that this is a fundamental aspect of the success or failure of the ACP. Prior to delivery of any exercise session, all PTIs must complete and pass a 5 day course covering all aspects of the ACP exercise sessions. PTIs are then advised to monitor aircrew technique during the exercises, provide coaching points as required and adjust the exercises to meet the needs of the individual. The PTIs and physiotherapists work with the aircrew during the exercises sessions with an aim of building strong therapeutic alliances to promote improved exercise adherence[20]. Once aircrew are competent in the exercises, they are then encouraged to continue with them as part of their normal weekly exercise routine, with adherence reviewed 6 months following the end of supervised sessions. Adherence to these exercises away from supervision will be reviewed as part of a further study.

A limitation of the study is that the quality of the written material sent to the experts may have hindered understanding of the practical nature of the exercises and supervision provided by the PTIs and physiotherapists.

In conclusion, the ACP has demonstrated excellent content validity for use with an aircrew population and for delivery by a team of trained PTIs and physiotherapists. The aircrew require additional supervision with the more complex neck exercises to enhance simplicity with the ACP. Whilst it is comprehensive in its detail, all the exercises are relevant to the population and the demanding environment they work in. Having established the content validity of the ACP, the next phase of this work was to establish its efficacy. The effect of the ACP on physiological performance in a high +Gz environment will now be investigated.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the panel of experts who reviewed the ACP and the physiotherapists, PTIs and aircrew involved in the development stage.

REFERENCES

1. Ang B, Harms-Ringdahl K. Neck pain and related disability in helicopter pilots: A survey of prevalence and risk factors. *Aviat Space Environ Med*. 2006;77:713-719.

2. Ang B, Linder J, Harms-Ringdahl K. Neck strength and myoelectric fatigue in fighter and helicopter pilots with a history of neck pain. *Aviat Space Environ Med*. 2005;76(4):375-380.

3. Ang BO, Monnier A, Harms-Ringdahl K. Neck/shoulder exercise for neck pain in air force helicopter pilots: A randomized controlled trial. *Spine (Phila Pa 1976)*. 2009;34(16):E544-51.

4. Bateman WA, Jacobs I, Buick F. Physical conditioning to enhance +Gz tolerance: Issues and current understanding. *Aviat Space Environ Med*. 2006;77(6):573-580.

5. Galvagno SM,Jr, Massa TV, Price SC. Acceleration risk in student fighter pilots: Preliminary analysis of a management program. *Aviat Space Environ Med*. 2004;75(12):1077-1080.

6. Green NDC. Protection against long-duration acceleration. In: Rainford DJ, Gradwell P, eds. *Ernsting's Aviation Medicine.* Fourth ed. London: Hodder Education; 2006:159-167.

7. Hides J, Lambrecht G, Ramdharry G, Cusack R, Bloomberg J, Stokes M. Parallels between astronauts and terrestrial patients - taking physiotherapy rehabilitation "to infinity and beyond". *Musculoskelet Sci Pract*. 2017;27 Suppl 1:S32-S37.

8. Lambrecht G, Petersen N, Weerts G, et al. The role of physiotherapy in the European Space Agency strategy for preparation and reconditioning of astronauts before and after long duration space flight. *Musculoskelet Sci Pract*. 2017;27 Suppl 1:S15-S22.

9. Lange B, Toft P, Myburgh C, Sjogaard G. Effect of targeted strength, endurance and coordination exercise on neck and shoulder pain among fighter pilots. A randomised-controlled trial. *Clin J Pain*. 2013;29:50-59.

10. Lynn MR. Determination and quantification of content validity. *Nurs Res*. 1986;35:382-385.

11. Naish R, Burnett A, Burrows S, Andrews W, Appleby B. Can a specific neck strengthening program decrease cervical spine injuries in a men's professional rugby union team? A retrospective analysis. *J Sports Science and Medicine*. 2013;12:542-550.

12. Netto KJ, Burnett AF, Coleman JL. Neck exercises compared to muscle activation during aerial combat manoeuvres. *Aviat Space Environ Med*. 2007;78:478-484.

13. Nilsson J, Friden C, Buren V, Ang BO. Development and validation of a web-based questionnaire for surveying skydivers. *Aviat Space Environ Med*. 2011;82:610-614.

14. Petersen N, Lambrecht G, Scott J, Hirsch N, Stokes M, Mester J. Postflight reconditioning for European astronauts - A case report of recovery after six months in space. *Musculoskelet Sci Pract*. 2017;27 Suppl 1:S23-S31.

15. Polit DF, Beck CT. The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing and Health*. 2006;29:489-497.

16. Polit DF, Beck CT, Owen SV. Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing and Health*. 2007;30:459-467.

17. Salmon DM, Harrison MF, Neary JP. Neck pain in military helicopter aircrew and the role of exercise therapy. *Aviat Space Environ Med*. 2011;82(10):978-987.

18. Salmon DM, Harrison MF, Sharpe D, Candow D, Albert WJ, Neary JP. Exercise therapy for improved neck muscle function in helicopter aircrew. *Aviat Space Environ Med*. 2013;84:1046-1054.

19. Slungaard E, McLeod J, Green NDC, Kiran A, Newham DJ, Harridge SDR. Incidence of G-induced loss of consciousness and almost loss of consciousness in the Royal Air Force. *Aerosp Med Hum Perform*. 2017;88(6):550-555.

20. Stokes M, Evetts S, Hides J. Terrestrial neuro-musculoskeletal rehabilitation and astronaut reconditioning: Reciprocal knowledge transfer. *Musculoskelet Sci Pract*. 2017;27 Suppl 1:S1-S4.

21. Walters L, Cho TH, Hendricks KA, et al. Validation of an exercise protocol targeted for military pilots. *Presentation at The Technical Cooperation Program Panel*. 2011.

22. Wickes SJ, Greeves JP. Prevalence and associated factors of flight-related neck pain. Farnborough:QinetiQ. 2006. 06/01069.