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COVID-19 lockdown: A global study investigating athletes' sport classification and sex on training practices

Original Scientific Research

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582 **COVID-19 lockdown: A global study investigating athletes' sport classification and sex**
583 **on training practices**

584 **ABSTRACT**

585 **Purpose:** To investigate differences in athletes' knowledge, beliefs, and training practices
586 during COVID-19 lockdowns, with reference to sport classification and sex. This work extends
587 an initial descriptive evaluation focusing on athlete classification.²¹ **Methods:** Athletes
588 (12,526; 66% male; 142 countries) completed an online survey (May-July 2020) assessing
589 knowledge, beliefs, and practices toward training. Sports were classified as Team sports (45%),
590 Endurance (20%), Power/technical (10%), Combat (9%), Aquatic (6%), Recreational (4%),
591 Racquet (3%), Precision (2%), Parasports (1%), and Others (1%). Further analysis by sex was
592 performed. **Results:** During lockdown, athletes practiced bodyweight-based exercises
593 routinely (67% females; 64% males), ranging from 50% (Precision) to 78% (Parasports). More
594 sport-specific technical skills were performed in Combat, Parasports, and Precision (~50%)
595 than other sports (~35%). Most athletes [range: 50% (Parasports) to 75% (Endurance)],
596 performed cardiorespiratory training (trivial sex differences). Compared to pre-lockdown,
597 perceived training intensity was reduced by 29–41%, depending on sport (largest decline:
598 ~38% in Team sports, unaffected by sex). Some athletes (range: 7–49%) maintained their
599 training intensity for strength, endurance, speed, plyometric, change-of-direction, and technical
600 training. Athletes who previously trained ≥ 5 sessions/week reduced their volume (range: 18–
601 28%) during-lockdown. The proportion of athletes (81%) training ≥ 60 -min/sessions reduced
602 by 31–43% during-lockdown. Males and females had comparable *moderate* levels of training
603 knowledge (56 vs 58%) and beliefs/attitudes (54 vs 56%). **Conclusions:** Changes in athletes'
604 training practices were sport-specific, with little-to-no sex differences. Team-based sports were
605 generally more susceptible to changes than individual sports. Policy makers should provide
606 athletes with educational resources to facilitate remote and/or home-based training during
607 lockdown-type events.

608 **Keywords:** Crowdsourced data, Multinational sample, Online survey, Perception, Remote
609 training

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617 **INTRODUCTION**

618 Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the resulting
619 COVID-19 pandemic transformed day-to-day life globally.¹ National and/or local authorities
620 adopted (and readopted) varying restrictive measures to curb virus spread, including closure of
621 borders and educational institutions alongside restriction of commercial activities.² Global
622 sporting calendars were severely disrupted at all levels, notably the postponement of the Tokyo
623 2020 Summer Olympics. Sport-specific training and recovery facilities alongside athlete
624 support services (e.g., sports science, sports medicine and allied health services) were at best
625 severely restricted and at worst unavailable.^{3,4} Consequently, athletes were house-bound for
626 prolonged periods, drastically modifying their daily lives and training practices.^{5,6}
627 Additionally, sleep,¹ mental health,⁷ and nutrition⁸ were all impacted.

628 Restrictive measures including social distancing, disrupted team and contact sport
629 athletes ability to practice sport-specific and/or contact intensive skills (e.g., rucking, mauling,
630 scrummaging and tackling in rugby⁹, or general team technical/tactical work).¹⁰ Training
631 intensity in professional handball players was reduced, with females showing a larger reduction
632 in weekly training days and hours than males,¹¹ suggesting differential effects of the lockdown
633 on athlete training due to sex. Training volume and intensity among professional cyclists during
634 a 7-week home confinement was reduced alongside maximal power output during 5- and 20-
635 min trials.¹² Weight-categorized athletes experienced challenges in maintaining optimal body
636 mass and composition during lockdown.¹³ Aquatic sports were almost completely ‘prohibited’
637 and thus likely severely compromised.¹⁴ Concerningly, individuals with disabilities (e.g.
638 Paraspport athletes) who often require highly specialized and/or bespoke training resources
639 (equipment and expertise) were particularly disadvantaged during the lockdown.¹⁵ Holistically,
640 it is clear near-all athletes (recreational, elite, or otherwise) were challenged practically and
641 psychologically to maintain their ‘normal’ training programs as a consequence of lockdowns.

642 During the first global lockdown, athletes were inclined to perform home-based
643 strength training activities such as bodyweight exercise, and use alternative endurance training
644 modalities such as a cycle ergometry.^{6,16} These strategies although preferable to training
645 cessation, have questionable effectiveness in providing sufficient training stimuli (whether for
646 maintenance or to drive adaptation) for high-level athletes. Given this unexpected autonomy,
647 many athletes’ individual knowledge and attitude towards training likely impacted their self-
648 regulation¹⁷ of training variables such as intensity, volume, and training mode. These individual
649 variations within- and between-sports may have impacted the way athletes attempted to
650 mitigate detraining effects during lockdown. Only scant information has been reported about
651 athletes’ knowledge, beliefs and attitudes toward training, and in turn how the understanding
652 of these issues ‘shaped’ training modifications during lockdown.

653 As alluded to above, potential sex differences regarding training maintenance during
654 lockdown may have been present, however, this assertion is based on a single sport (i.e.,
655 handball), and the question has not been explored extensively. That said, female athletes during
656 lockdown were more likely to experience mental health issues compared to male athletes,
657 including depressive feelings, energy loss, and reduced motivation according to one data set.⁶
658 Specifically, female athletes tended to be more anxious¹⁸ and reported mood disruptions related
659 to increased perceived stress and dysfunctional psycho-biosocial states.¹⁹ Further, female
660 athletes with underlying medical conditions (e.g., menstrual dysfunction such as
661 endometriosis) may have had reduced access to appropriate medical care during the lockdown

662 period.²⁰ When considering the challenges female athletes experienced during lockdown, lower
663 classification athletes appear more likely to be disadvantaged.²¹

664 This study assessed the knowledge, beliefs/attitudes, and practices toward training and
665 its interruption during the 2020 early COVID-19 lockdown period. Specifically, how these
666 issues were moderated by sport classification and sex were explored. The data will extend the
667 initial analyses of the study focusing on overall outcomes and athlete classification²¹ to provide
668 specific evidence to support individuals and sporting teams, sport governing bodies, and
669 governments in developing practical guidelines, coaching practices, educational resources for
670 athletes, and/or policies and procedures to optimise their responses to future restrictions or
671 lockdowns.

672 **METHODS**

673 **Participants**

674 A sample of athletes (n = 12,526; representing 142 countries/territories across six
675 continents) participated in the current study. Participant eligibility is described elsewhere
676 (open-access).²¹ Informed consent was provided by participants under ethical approval from:
677 (i) University of Melbourne, Australia (HREC No. 2056955.1); (ii) Qatar University, Qatar
678 (QU-IRB 1346-EA/20); and (iii) University of Cassino e Lazio Meridionale, Italy (10031), in
679 the spirit of the Declaration of Helsinki.

680 **Design**

681 A within-subject, cross-sectional, questionnaire study design was utilized. Providing
682 further novel analyses from the collaborative ECBATA project²¹. Specifically, whether
683 COVID-19 lockdown effects on athlete training were moderated by sport classification and/or
684 sex. The full questionnaire is available in open access format.²¹

685 **Procedures**

686 An online survey (35 different languages) was disseminated via Google Forms from
687 May to July 2020 (50 days). The survey was distributed and promoted via e-mail,
688 personal/group messaging applications and social media through the professional networks of
689 the research team. Question data were converted directly into standardized codes/numbers, and
690 checked for veracity, to facilitate statistical modelling. Cronbach's alpha of 0.82 to 0.97²¹
691 demonstrated *good* to *excellent* reliability of the questionnaire.²² The survey was developed
692 initially by JAW and KC, then reviewed and revised by the wider authorship team, involving
693 >100 researchers from >60 countries. The 59 questions were related to athletes' training
694 knowledge, beliefs/attitudes, and practices as described elsewhere.²¹ Beliefs and attitudes are
695 individually held; belief is related to expression of what is thought or believed; and attitude is
696 a psychological tendency or mental predisposition, which influences how an individual behaves
697 optimistically towards key issues.²¹ Sport classification was self-report by athletes, yielding
698 108 different sports (and disciplines within sports). Some sports were specifically reported,
699 e.g., BMX, road or track cycling (for cycling), and marathon, road running, or athletics (for
700 athletics). For athletes who reported more than one sport, the first identified sport was
701 considered the 'main' sport. For sex comparisons only, 31 athletes who indicated a non-binary
702 'sex' or did not indicate 'sex' (male/female) were excluded, to enable binary statistical

703 comparisons. Where sex comparisons are stated/inferred, this indicates they have been
704 completed in a binary whole sample manner. Sport specific comparisons by sex within each
705 sport classification, can be found in Table 2, Figures 2-5, and Supplementary (S) Table (S7).

706 Sub-groups for: (a) able-bodied; and (b) para-athletes (i.e., *Parasports*; defined as
707 individuals requiring special assistance, or with a disability) were coded and analyzed
708 separately due to sampling power requirements. Using a *best-fit approach* and aggregation,
709 able-bodied sports were classified into nine sport classifications and differentiated further by
710 competitive level and recreational (i.e., *Recreational*; non-competitive participation or physical
711 activities, usually for leisure, health or work-related) sports. Similarly, competitive sports were
712 further sub-grouped, as follows: (i) self-dependent training in nature without or with own
713 equipment, and those relatively longer in duration [i.e., *Endurance*; e.g., triathlon, cross
714 country, and road cycling]; (ii) self-dependent training with technical concerns, and/or specific
715 equipment not usually owned or easily accessible [i.e., *Power/technical*; e.g., field-events in
716 athletics, weightlifting, and CrossFit®]; (iii) interactive or dependent on team mates [i.e.,
717 *Team*; e.g., hockey, rugby, and volleyball] or sparring/fighting [i.e., *Combat*; e.g., Muay Thai,
718 Ju-jitsu, and wrestling]; (iv) one or more combinations of these criteria and type of sport, e.g.
719 water-based [i.e., *Aquatic*; e.g., water polo, canoe, and sailing], racquet-based [i.e., *Racquet*;
720 e.g., tennis, badminton, and squash], and target-based [i.e., *Precision*; e.g., archery, shooting,
721 and bowling]; and (v) other than the seven classifications for competitive sports, or relatively
722 competitive sports but hardly participated [i.e., *Other*; e.g., wheel gymnastic and aerial silks]
723 (Figure 1).

724 ***Figure 1 here please ***

725 The knowledge section comprised 10 questions (9 scored questions), using a 5-point
726 Likert scale (1 = strongly agree; 5 = strongly disagree; with an addition to ‘don’t know’
727 option).²¹ The belief and attitude section comprised 14 questions (same 5-point Likert scale),
728 with 7 scored questions. Correct (for knowledge) or positive (for beliefs/attitudes) answers
729 (e.g., strongly agree/agree or strongly disagree/disagree with a statement) were scored as “1.”
730 The other answers received a score of “0” (including the statements “neutral” or “don’t know”).
731 The total score (converted in percentage) was used to rank the level of knowledge and
732 beliefs/attitudes based on previously established thresholds: $\geq 70\%$ as good, $\geq 51\text{--}<70\%$ as
733 moderate, and $\leq 50\%$ as poor for athlete/classification comparisons.²¹ The practice section
734 comprised 11 questions, involving an array of question styles to establish training practices,
735 including: (i) selecting one or more predefined answers; (ii) comparing related pre- to during-
736 lockdown effects on training practices; (iii) yes or no; and (iv) sub-questions including a free-
737 text cell to capture details.²¹

738 **Statistical analysis**

739 All data were coded with statistical analyses performed using SPSS v.26 (IBM,
740 Chicago, Illinois, USA). Data are presented using a variety of appropriate descriptive statistics,
741 including frequencies, percentages, and mean \pm standard deviation. Knowledge and
742 beliefs/attitudes scores across sex and sport classifications were compared using an
743 independent t-test and one-way ANOVA with Bonferroni post-hoc test, respectively.
744 Relationships between categorical variables were assessed using Chi-Square (χ^2) test for
745 independence. Subsequently, analysis of adjusted residuals was performed to identify which
746 subgroups contributed the most (*residual greater than 1.96; i.e., significantly higher*) or the
747 least (*residual less than -1.96; i.e., significantly lower*) to the relationships, which corresponds

748 to $p < 0.05$. A McNemar-Bowker test was utilized to compare frequency and duration of training
749 before vs. during lockdown within athletes. The odds ratio (OR), with a 95% confidence
750 interval (CI), was used to estimate the strength of the relationship of bivariate variables by sex.
751 Only those ORs were considered where the 95% CI did not include 0.91-1.10 range (10%
752 change, based on $1/1.1 = 0.91$ and $1*1.1 = 1.10$). A difference of $< 10\%$ was deemed unclear
753 for both sport and sex comparison. A p-value of < 0.05 was considered significant.

754 **RESULTS**

755 *Demographic characteristics*

756 A majority of the participants were involved in Team (45%) or Endurance (20%) sports,
757 with two-thirds of male athletes (66%) (Table 1).

758 ***Table 1 here please***

759 ***Table 2 here please***

760 *Training knowledge and beliefs/attitudes*

761 Overall scores for knowledge and beliefs/attitudes toward training during lockdown,
762 for both male and female athletes, are presented in Table 2. For both scoring scales, male and
763 female athletes had a *moderate* level of knowledge and beliefs/attitudes. The nine questions
764 (and aggregated answers) for knowledge towards training according to sport classification and
765 sex are provided as Supplementary, Tables S1 and S2. The corresponding seven questions for
766 beliefs/attitudes towards training are provided in Tables S3 and S4, respectively. Finally, the
767 questions and answers related to knowledge and beliefs/attitudes according to sport
768 classification and sex are shown in Tables S5 and S6, respectively.

769 ***Table 3 here please***

770 ***Table 4 here please***

771 *Training practices*

772 The most frequent purpose of the athlete's training during lockdown, regardless of sport
773 classification, was to maintain or develop general fitness and health (Table 3), with males
774 (81%) and females (85%) displaying high training frequency (Table 4). The training program
775 was either prescribed by the athletes themselves, the coach, or a combination of both, but male
776 athletes were more likely ($p < 0.001$) to perform their own training program than female athletes
777 during lockdown. Both male (80%) and female (79%) athletes generally trained alone, with
778 Precision sports to a lesser degree than other sports ($p < 0.05$) (Table 3). Body-weight-based
779 exercises were most consistently performed during lockdown [67% and 64% for female and
780 male athletes, respectively ($p < 0.001$)]; ranging from 50% (Precision sports) to 78%
781 (Parasports). Cardiorespiratory training was also consistently performed by most athletes,
782 ranging from 50% in Parasports to 75% in Endurance sports. Other exercise forms (e.g.,
783 strength and plyometric training) were less regularly performed (~20-50%, depending on sport
784 classification), but sport-specific technical skills were more regularly performed (~50%) in
785 Combat, Parasports and Precision compared to the other sports (~35%) ($p < 0.05$). Less than
786 half of the athletes (7-49%, depending on sport classification) were able to maintain the same
787 intensity during strength, endurance, speed, plyometric, change of direction, and technical
788 training when compared to pre-lockdown (Table 3). Most athletes, 85% of females and 80%
789 of males, reported being able to perform warm-up and stretching with the same pre-lockdown
790 intensity during the lockdown (Table 4).

791 ***Figure 2 here please ***

792 ***Figure 3 here please ***

793 ***Figure 4 here please ***

794 Comparisons of weekly training frequency, session duration and training intensity
795 before, and during lockdown between sports and sex are shown in Figures 2, 3, and 4,
796 respectively. During lockdown, the frequency of training dropped for all sport classifications
797 ($p < 0.001$). Similarly, the number of athletes performing >60-min/session training was much
798 lower during lockdown for all sport classifications, ranging from 31 to 43% of the athletes.
799 Team sports showed the highest reduction in training intensity (59%), a significantly larger
800 reduction than reported for Aquatic, Endurance, Power/technical, and Precision sports. Within
801 each sport, training frequency (except 'Other Female') and duration from before- to during
802 lockdown in male and female athletes were reduced ($p < 0.05$). As a whole sample, reduction
803 in training intensity was the same for male and female athletes (~38%); with a disparity of 0-
804 6% between males and females within different sports.

805 ***Figure 5 here please***

806 Figure 5 shows that 44-84% of the athletes reported sufficient access/space and the
807 necessary equipment to train during lockdown, depending on sport classification. Overall, a
808 higher degree of access/space and necessary equipment was reported for cardiorespiratory
809 training compared to strength and technical training. Male and female athletes were similarly
810 affected (i.e., ranging from 3-6% difference between sexes, $p < 0.05$) in terms of technical
811 (access/space/necessary equipment) and cardiovascular (necessary equipment) training. Some
812 disparity in sex distribution is evident for selected variables in different sport classifications
813 (Figure 5).

814 **DISCUSSION**

815 Most of the observed lockdown mediated changes in training practices of athletes were
816 likely mediated by the nature of the sports themselves. Individual and less equipment-intensive
817 sports (e.g., Endurance sports) were easier to maintain during lockdown than more technically
818 demanding sports (e.g., Racquet and Team sports) requiring a partner, teammates and/or
819 specialist equipment. In some sports, shifting/adaptation of training practices was necessary to
820 provide specific training benefits. Within this context, Combat sport athletes implemented
821 more practical fitness exercises such as plyometric training, skills and technical development,
822 while Aquatic sports athletes were self-adjusting by amplifying their pre-lockdown dry-land
823 workouts, including cardiorespiratory-based fitness. Based on overall data, the pandemic
824 subjectively affected the training routines of male and female athletes similarly, although these
825 differences were slightly disproportionate in some cases e.g., mental aspect (44% males vs 48%
826 females, respectively), including inconsistencies within sports, e.g., Aquatic and Parasports.
827 Although some sex differences were observed in overall data (0% to 6%), the magnitudes are
828 probably not meaningful in practical terms. The scores or perceptions in training knowledge
829 and beliefs/attitudes between sexes were similarly (~50-60%) rated as *moderate* by the
830 employed criteria. The sex data suggest that future lockdown type events do not require policy
831 or guidance to be wholly modified based on sex (although there are some nuances to consider),
832 whilst sport classification would benefit from such consideration and individualization.

833 Sports can be classified across a continuum ranging from individual to interactive, the
834 latter involving teammates and/or direct opponents.²³ Seemingly, these characteristics

835 modified athletes training modifications in response to lockdown. Indeed, more Endurance
836 athletes trained alone during lockdown than other sports. The training of Endurance athletes
837 typically involves a combination of low-intensity continuous work [below anaerobic threshold
838 (AT)] and high-intensity interval training (at or above AT).²⁴ This training can be achieved
839 using a home-based treadmill, cycle-rollers, or a rowing ergometer, if outdoor training is not
840 viable. Interestingly, 40% of Power/technical athletes were able to implement strength training,
841 more than other sports, which also encompassed pre-lockdown training intensity (36%) and
842 plyometric training (32%). Evidently, some athletes were already in possession or were able to
843 prepare/buy/borrow the necessary equipment (specialised or otherwise) prior to lockdown.²⁵
844 Concerning training facility access, elite athletes were less affected by lockdowns than their
845 lower-level counterparts.²¹ In contrast, Combat sport athletes had to change their training focus
846 and methods to a larger extent given the higher probability of virus transmission during close
847 contact interactions.²⁶ Consequently, these athletes employed a greater focus on
848 skills/technique development, combat simulations, plyometric training, endurance training, and
849 weight management during lockdown.

850 Despite pool closures, Aquatic athletes found functional substitutes to their routines,
851 with relatively more Aquatic athletes training for general fitness and health (87%) compared
852 to others [e.g., Power/technical (78%)]. These aquatic sports athletes adopted a wide range of
853 training modalities, including body weight-based exercises, especially females [e.g., abdominal
854 strength (aquatic female 63% vs male 48%) and flexibility (female 56% vs male 44%)],
855 strength training, technical simulation, and cardiovascular training, while observing weight
856 management (female 57% vs male 47%). Performing dry-land activities may maintain fitness
857 during pool closures and could enhance selected performance components when resuming
858 regular aquatic training. For example, enhanced strength and power in the lower limbs may
859 improve the starting dive of swimmers.¹⁴ Similarly, Precision sports athletes found substitutes
860 for their pre-lockdown training. Unable to train with their rifles, archers, or ball/pins, many
861 athletes from these sports utilized strength training (40%) to enhance their muscular abilities
862 in place of refining their skills/techniques; using a program provided by their coaches or self-
863 prescribed. These activities could help athletes improve selected components of their sports
864 performance via increased precision, constancy and stability (e.g., for shooting) as a result of
865 improved muscular strength and aerobic capacity.²⁷ It is noteworthy that within a small sample
866 in Parasports, a higher proportion of athletes (78%) performed body-weight-based exercises,
867 with some sex disparity evident, i.e., 85% females and 67% males. During lockdown, resistance
868 training can be performed in different ways to achieve specific objectives, albeit necessitating
869 some creativity using different types of training, dependent on location.²⁵ Nevertheless, despite
870 being able to maintain elements of routine practices, some key variables such as training
871 intensity were likely compromised during lockdown.²⁵ Clearly, athletes wishing to elicit
872 specific adaptive responses in terms of training goals must manipulate or modify the key
873 training variables accordingly, including training duration, intensity, type of exercise, and
874 frequency. These adaptations may lack efficacy regarding maintenance or development of
875 physical and/or technical attributes.

876 Insufficient and/or inappropriate training stimuli in key training variables such as
877 intensity and frequency can lead to de-training.^{28,29} In the current study, during lockdown, more
878 than 50% of the athletes were unable to maintain pre-lockdown intensity during strength,
879 endurance, speed, plyometric training, change-of-direction, and technical training. Depending
880 on sport classification, and excluding recreational athletes, 68 to 87% of the athletes were
881 training ≥ 5 times/week before lockdown. The number of athletes who trained at the same
882 frequency during lockdown was reduced by $\sim 20\%$ to 30% (Figure 2). Moreover, depending on

883 sports, and excluding Recreational and Other sports, the number of athletes who spent pre-
884 lockdown training of ≥ 60 -min/session (i.e., $>81\%$) was greatly reduced by ~ 30 to 40% during
885 lockdown (Figure 3). This outcome indicates that many athletes were unable and/or unwilling
886 to reach their typical pre-lockdown training session duration during lockdown conditions. The
887 observed reductions in these training variables might be partly influenced by limitations in the
888 available training space/access and necessary equipment; with male and female athletes
889 similarly affected (Figure 5). Such findings were observed despite relatively fewer female
890 athletes involved in Team sports, which was one of the sport classifications most affected by
891 lockdown. Globally, handball players reported their activities of moderate and vigorous
892 intensity declining during lockdown, forfeiting physiological capacities and performance.³⁰
893 Similarly, again in handball players, reductions in weekly training days and hours due to
894 lockdown were reported, with a greater decline among female athletes.¹¹ In the current study,
895 Team sports athletes were much less likely to perform specific training at an intensity similar
896 to pre-lockdown, especially for technical skills, speed endurance, and long endurance (Table
897 3). Sport-specific manoeuvres including rucks, mauls, scrums and tackling in rugby usually
898 implemented with a partner/teammate,⁹ appeared limited. Overall, the COVID-19 lockdown
899 provided unique and sports-specific challenges that the athletes and coaches had to counter to
900 preserve the frequency, intensity, and duration of training. There was a substantial effort by
901 coaches, athletes, support staff, and teams/organization to maintain or improve performance,
902 or some elements of the performance components, irrespective of sport and sex. Nevertheless,
903 these modifications may lack the desired efficacy.

904 The scores of the knowledge and beliefs/attitudes toward training were classified
905 *moderate*, irrespective of sports except for recreational-level and ‘Other’-sports athletes who
906 were classified as *poor* for beliefs/attitudes. Endurance sports scored higher than most other
907 sports in beliefs/attitudes, whereas athletes in Precision and Recreational sports exhibited lower
908 training knowledge scores. The observation that the level of physical activities of Endurance
909 athletes during lockdown can be maintained, likely reflects their abilities to self-regulate
910 training. Endurance athletes were able to essentially replicate their pre-lockdown regular
911 exercises, especially for cardiorespiratory-based training. In contrast, the scores of
912 beliefs/attitudes in Recreational sports were at the lower end of the spectrum (Table 2),
913 indicating a need for more upskilling related to training-related educational resources on the
914 impacts of training or de-training; perhaps with a focus towards both health and performance.
915 Further education and upskilling might positively influence training intensity, frequency, and
916 volume to improve or maintain performance.^{28,29,31}

917 Meanwhile, the absence of competition and *normal* training seems to have affected
918 many athletes, especially in Team and Racquet sports, with some (Team and Combat sports)
919 revealing the importance of having teammates (and/or even opponents) present to “do more in
920 training”.²³ Indeed, the competitive elements and positive behavioural/performance responses
921 when training with²³ and/or competing against other athletes²³ are well known. In contrast,
922 training alone might be unfavourable, particularly within female athletes within the present
923 study given their increased anxious feelings and mental vulnerability during lockdown (i.e.,
924 higher proportion) compared to males. The data and discussion above, emphasize the important
925 role sporting organizations and clubs did and can play to facilitate virtual or online competitive
926 opportunities for all athletes during lockdown and beyond. Finally, despite a disparity in sex
927 sample size, the discrepancy is comparable to sport participation data elsewhere (e.g., 40%
928 female, 60% male in the United States)³² and the participant sex bias in scientific research *per*
929 *se* (65% male and 35% female) within sports science and medicine.³³

930 **PRACTICAL APPLICATIONS**

931 These sports-specific data, discussion, and recommendations should inform
932 government and sporting organization action plans, and arrangements for teams and individual
933 athletes during lockdown-like events or situations. Most of the observed changes in athletes'
934 training practices during the 2020 first COVID-19 lockdown were sports-specific, with trivial
935 to small differences between male and female athletes. Maintenance of sport-specific training
936 practices were easier in individual and less equipment-dependent sports like Endurance sports,
937 compared to more technically demanding sports. Interactive sports such as Team sports were
938 most dramatically impacted. Regardless of sport and sex, lockdown had negative impacts on
939 the athletes' key training variables, including training intensity, duration, frequency, and type.
940 Training for muscular strength, endurance, speed, plyometric, change of direction, and
941 technical aspects had been compromised. Differences in athletes' knowledge and beliefs
942 between sexes were trivial, and lockdown-specific educational materials (e.g., sports sciences,
943 training/performance, and motivation-related sessions/interactions), which can be facilitated
944 by other types of assistance (e.g., free-internet and financial incentives) should be considered,
945 irrespective of sex. Utilization of new technology like virtual reality and mobile applications
946 for training, training monitoring, and educational purposes may be useful during lockdown.²
947 Also, we recommend the development of specific policy responses to help athletes maintain
948 training (and competition) comparable to normal levels in future periods of lockdown.
949 Although logistically intensive, *bubble* training or competition approaches may provide the
950 avenue for athletes to maintain training (and compete) similarly to normal levels;^{4,34,35} but
951 caution should be taken that prolonged *bubble* camps may be psychologically challenging for
952 some athletes.³⁵

953
954 **CONCLUSIONS**

955 The data suggest that future lockdown type events do not require policy or guidance to
956 be wholly modified based on sex (although there are some nuances to consider, e.g., in
957 Recreational and Parasports. In contrast, athletes in selected sports (identified by sport
958 classification) would likely benefit from specific training management and individualization.
959 Most of the observed changes in the training practices of athletes during the first COVID-19
960 lockdown were mediated by the nature of the sports, with little to no differences for sex.
961 Maintenance of sport-specific training practices was easier in individual and less equipment-
962 dependent sports (e.g., Endurance sports), compared to more technically demanding sports and
963 especially team sports. Knowledge, beliefs and practices on training were broadly similar
964 between male and female athletes, and across sport classifications, with the exception of
965 recreational athletes who had a lower score (*poor* compared to *moderate*) for the training
966 beliefs/attitudes.

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975 The authors declare that they have no competing interests

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Figures Legends

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1099 **Figure 1.** Flow diagram outlining sport classification process.

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1101 **Figure 2.** Training frequency of ≥ 5 times per week based on sport classification and sex
1102 before and during lockdown (n = 11,626).

1103 Ordered from smallest to largest reductions. %, within sex or within sports, which represent
1104 'yes' answer relative to 'no' answer; ^a, significantly higher; ^b, significantly lower at $p < 0.05$;
1105 Note, changes from before lockdown to during lockdown for all variables were significant (p
1106 < 0.05) except 'Other Female'; AQUA = aquatic, COMB = Combat, ENDU = Endurance,
1107 PARA = Parasports, PO/T = Power/technical, PREC = Precision, RACQ = Racquet, RECR =
1108 Recreational, TEAM = Team, Other = Others.

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1110 **Figure 3.** Training duration of ≥ 60 -min per session based on sport classification and sex
1111 before and during lockdown (n = 12,241).

1112 Ordered from smallest to largest reductions. %, within sports or within sex, which represent
1113 'yes' answer relative to 'no' answer; ^a, significantly higher; ^b, significantly lower at $p < 0.05$;
1114 Note, changes from before lockdown to during lockdown for all variables were significant (p
1115 < 0.05); AQUA = aquatic, COMB = Combat, ENDU = Endurance, PARA = Parasports,
1116 PO/T = Power/technical, PREC = Precision, RACQ = Racquet, RECR = Recreational,
1117 TEAM = Team, Other = Others.

1118

1119 **Figure 4.** Training intensity during lockdown session based on sport classification and sex.

1120 *Question:* Do/did you maintain your pre-lockdown intensity for sports specific training
1121 (practicing your sport) during the lockdown? Can you estimate how much in percentage?
1122 (100% represents the same intensity as before the lockdown).

1123 Ordered from smallest to largest reductions. Data are mean \pm SD; AQUA = aquatic, COMB =
1124 Combat, ENDU = Endurance, PARA = Parasports, PO/T = Power/technical, PREC =
1125 Precision, RACQ = Racquet, RECR = Recreational, TEAM = Team, Other = Others; O =
1126 overall data, M = male, F = female; note, all comparisons between male and female athletes
1127 were significant at $p < 0.001$.

1128 The whisker plot includes 5 number-summary (lowest to highest): minimum, first quartile,
1129 median, third quartile, and maximum. The maximum or minimum number in the dataset,
1130 respectively is shown by the upper extreme or lower extreme of the whisker/chart (excluding
1131 outliers). Upper (third) and lower (first) quartiles, respectively are the 75th and 25th
1132 percentiles. The median (middle of data set) is shown as a line in the center of each box; ⁺,
1133 mean values.

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1135 **Figure 5.** Reported practices for space/access and equipment to training based on sport
1136 classification and sex (n = 11,451).

1137 *Question:* Do/did you have **(A)** sufficient space/access, and **(B)** necessary equipment to train
1138 for:

1139 %, within sex or within sports, which represent ‘yes’ answer relative to ‘no’ answer; ^a,
1140 significantly higher; ^b, significantly lower at p<0.05; *, significantly higher than male; AQUA
1141 = aquatic, COMB = Combat, ENDU = Endurance, PARA = Parasports, PO/T =
1142 Power/technical, PREC = Precision, RACQ = Racquet, RECR = Recreational, TEAM = Team,
1143 Other = Others.

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1167 **Table 1.** Demographic characteristics of participants by sport classification and sex.
 1168 Between-sports proportion entails a comparison between all sports within a specific sex only.

	Total (n = 12526)	Total, %	Male proportion (n = 8265) %	Female proportion (n = 4230) %	Between- sports proportion (male) %	Between- sports proportion (female) %
Team	5600	45	71	29	48	38
Endurance	2465	20	66	34	20	20
Power/technical	1212	10	61	39	9	11
Combat	1188	9	64	36	8	10
Aquatic	704	5	51	49	4	8
Recreational	469	4	63	37	4	4
Racquet	405	3	59	41	3	4
Precision	313	2	53	47	2	3
Parasports	95	1	62	38	1	1
Other	75	1	65	35	1	1
		100			100	100

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 1170 Note: 31 athletes indicated a non-binary ‘sex’ or did not indicate ‘sex’ (male/female) and
 1171 were excluded for sex comparison

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1190 **Table 2.** Comparison of knowledge and beliefs/attitudes related to training interruptions
 1191 during lockdown, based on sport classification (n = 12,526) and sex (n = 12,495).

	Knowledge (0-100%)	BA (0-100%)	Knowledge		BA	
			Male (0-100%)	Female (0-100%)	Male (0-100%)	Female (0-100%)
Aquatic	59 ± 18	56 ± 20	57 ± 19	60 ± 16	55 ± 22	57 ± 19
Combat	57 ± 18	54 ± 21	57 ± 19	57 ± 17	53 ± 22	55 ± 20
Endurance	57 ± 17	57 ± 22	56 ± 18	58 ± 16	57 ± 23	59 ± 21
Parasports	60 ± 16	57 ± 19	63 ± 14	57 ± 19	57 ± 19	58 ± 20
Power/technical	56 ± 20	54 ± 24	55 ± 21	58 ± 18	53 ± 25	55 ± 22
Precision	51 ± 18	51 ± 22	53 ± 18	50 ± 18	53 ± 20	49 ± 23
Racquet	56 ± 18	56 ± 22	56 ± 18	56 ± 17	56 ± 23	57 ± 21
Recreational	51 ± 21	48 ± 29	50 ± 21	53 ± 19	46 ± 29	52 ± 28
Team	57 ± 19	55 ± 23	56 ± 19	59 ± 17	54 ± 24	57 ± 22
Other	50 ± 19	51 ± 21	49 ± 20	53 ± 17	49 ± 22	55 ± 19
Male	56 ± 19	54 ± 24				
Female	58 ± 17	56 ± 22				

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1193 Data are mean ± SD; Scoring threshold: ≥70% = good, >50-<70% = moderate, and ≤50% =
 1194 poor; BA = beliefs/attitudes.

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Table 3. Athlete practices during COVID-19 lockdown based on sport classification.

	Percentage of respondents									
	AQUA	COMB	ENDU	PARA	PO/T	PREC	RACQ	RECR	TEAM	Other
1. What are/were your general purpose(s) of training during the lockdown? (n = 12,385)										
M/d general fitness & health *	87 ^a	84	85 ^a	90	78 ^b	78 ^b	87 ^a	82	82 ^b	73 ^b
M/d skills/technique *	37 ^b	55 ^a	38 ^b	55 ^a	44	58 ^a	37 ^b	31 ^b	43	51
M/d strength and power *	54	53	52 ^b	54	55	56	55	46 ^b	56 ^a	55
M/d muscular endurance *	55	58 ^a	54	59	52 ^b	56	56	49 ^b	55	44
M/d abdominal strength *	55 ^a	46	49	59 ^a	47	35 ^b	49	45	48	43
M/d aerobic fitness *	57 ^a	50	56 ^a	51	49	46	49	48	47 ^b	43
M/d general flexibility *	49 ^a	50 ^a	45	47	43	35 ^b	44	41	42 ^b	43
Improve muscle balance *	38	39	35	34	37	38	37	32	37	33
Weight management *	52 ^a	51 ^a	48	51	44	48	50	54	47	41
<i>Note: M/d = Maintain or develop</i>										
2. Who is prescribing / prescribed the training program during the lockdown? (n = 12,351)										
Own training program *	35 ^b	47 ^a	41	31 ^b	39 ^b	39	45	39	45	53
From coach or trainer *	43 ^a	40	38 ^b	57 ^a	44 ^a	44	40	39	39	29
Combination of above *	44 ^a	36	38	38	35	46 ^a	36	33	35 ^b	25 ^b
Found from an external source *	26	23	22 ^b	12 ^b	20 ^b	23	30 ^a	34 ^a	28 ^a	23
3. Do/did you train (with)? (n = 12,347)										
Alone *	80	80	82 ^a	85	80	73 ^b	77	79	79	83
Partners, similar-level fitness *	34 ^a	29	30	27	28	37 ^a	34 ^a	23 ^b	28 ^b	29
Partners, different-level fitness *	19	18	22	20	17 ^b	20	19	16	18	20
4. What are the type of exercises that you are doing / have been doing consistently (at least twice a week) during lockdown? (n = 12,522)										
Body-weight based/limited equipment *	70 ^a	65	65	78 ^a	63	50 ^b	64	62	66	51 ^b
Weightlifting/strength training *	37 ^a	34	27 ^b	40	40 ^a	27	33	24 ^b	32	35
Technical skills (sport specific) *	36 ^b	53 ^a	33 ^b	51 ^a	35	47 ^a	34	31 ^b	35 ^b	37
Imitation of techniques *	30 ^a	42 ^a	22 ^b	26	24	30 ^a	30 ^a	22	21 ^b	31
Cardio training, including HIIT *	67 ^a	51 ^b	75 ^a	50	54 ^b	52 ^b	63	55	54 ^b	56
Plyometric training	24	29 ^a	26	12 ^b	29 ^a	17 ^b	27	19 ^b	25	29
5. What are the types of specific training you are/were able to do with the same intensity during the lockdown (very similar to pre-lockdown)? (n = 12,522)										
Warm up and stretching *	85 ^a	84 ^a	80	85	83	79	79	80	81	78
Weightlifting/strength training *	33	33	30 ^b	41	36 ^a	32	34	27	34	30
Plyometric training *	27	35 ^a	31	14 ^b	32	22 ^b	28 ^b	24	30	28
Technical skills (sport-specific) *	29	46 ^a	29	39	30	45 ^a	29	29	28 ^b	38
Speed training *	23 ^b	29 ^a	29 ^a	31	23 ^b	20 ^b	31	24	27	20
Speed endurance *	30	30	33 ^a	28	25 ^b	17 ^b	30	26	27 ^b	23
Long endurance *	44 ^a	35 ^b	49 ^a	32	37	33	39	34 ^b	35 ^b	38
Interval/intermittent training *	41 ^a	33	45 ^a	33	36	31	38	38	30	30
Change of directions *	8 ^b	20 ^a	12 ^b	9	9 ^b	7 ^b	16	15	18 ^a	7 ^b

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1217 For all questions, athletes were allowed to select multiple answers; %, within sport
 1218 classification, represent 'yes' answer, relative to 'no' answer; *, significant relationship with
 1219 sport classification; ^a, significantly higher; ^b, significantly lower at p<0.05; AQUA = aquatic,
 1220 COMB = Combat, ENDU = Endurance, PARA = Parasports, PO/T = Power/technical, PREC
 1221 = Precision, RACQ = Racquet, RECR = Recreational, TEAM = Team, Other = Others. Note:
 1222 this Table is in conjunction with Table S7 (supplementary) that include details of male and
 1223 female athletes; answer's selections are shortened, long version can be seen in Table 4.

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Table 4. Practices during COVID-19 lockdown by athletes based on sex.

	Male %	Female %	OR (95% CI)*
1. What are/were your general purpose(s) of training during the lockdown? (n = 12,385)			
Maintain or develop general fitness and health	81	85	0.78 (0.70–0.86)
Maintain or develop skills/technique	41	45	0.84 (0.78–0.91)
Maintain or develop strength and power	54	55	0.97 (0.90–1.05)
Maintain or develop muscular endurance	54	57	0.88 (0.82–0.95)
Maintain or develop abdominal strength	46	52	0.80 (0.74–0.86)
Maintain or develop aerobic fitness	50	50	0.99 (0.92–1.06)
Maintain or develop general flexibility	41	48	0.76 (0.70–0.82)
Improve muscle balance	35	39	0.87 (0.80–0.94)
Weight management	46	51	0.84 (0.78–0.90)
2. Who is prescribing / prescribed the training program during the lockdown? (n = 12,351)			
Own training program	46	37	1.46 (1.35–1.57)
Training program from my coach or trainer	39	42	0.88 (0.82–0.95)
Combination of own training and my coach/trainer	35	40	0.79 (0.73–0.85)
Found training material from an external source: online/social media/TV, a friend etc.	23	30	0.72 (0.66–0.79)
3. Do/did you train? (n = 12,347)			
Alone	80	79	1.03 (0.94–1.13)
In a small group of partners of equal athletic capacity	29	30	0.92 (0.85–1.00)
With family members or friends with little athletic capacity	18	21	0.81 (0.74–0.89)
4. What are the type of exercises that you are doing / have been doing consistently (at least twice a week) during lockdown? (n = 12,522)			
Body-weight based exercises with limited equipment	64	67	0.84 (0.78–0.91)
Weightlifting (strength) training	32	32	1.00 (0.92–1.08)
Technical skills (sport specific)	36	38	0.93 (0.86–1.01)
Imitation or simulation of the techniques	24	26	0.90 (0.82–0.98)
Cardiovascular training, including HIIT	60	61	0.88 (0.82–0.95)
Plyometric training (repeated jumping)	25	27	0.90 (0.83–0.98)
5. What are the types of specific training you are/were able to do with the same intensity during the lockdown (very similar to pre-lockdown)? (n = 12,522)			
Warm up and stretching	80	85	0.72 (0.65–0.79)
Weightlifting (strength) training	34	31	1.16 (1.07–1.26)
Plyometric training (e.g., repeated jumping)	29	32	0.86 (0.79–0.93)
Technical skills (sport-specific)	30	33	0.88 (0.81–0.95)
Speed training	27	26	1.06 (0.98–1.16)
Speed endurance	29	27	1.08 (1.00–1.18)
Long endurance	40	37	1.13 (1.05–1.22)
Interval/intermittent training	34	37	0.88 (0.81–0.95)
Change of directions	15	14	1.08 (0.98–1.21)

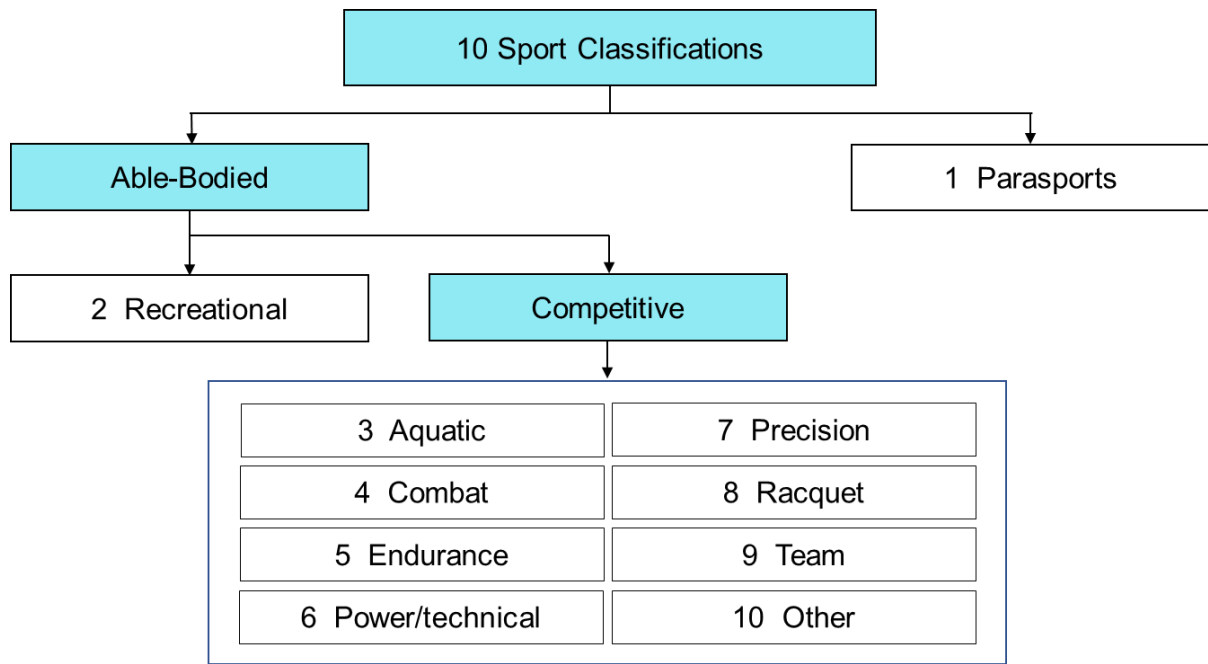
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1227 For all questions, athletes were allowed to select multiple answers; valid % computed
 1228 excluding missing values, within sex, represent ‘yes’ answer, relative to ‘no’ answer. * Ratio
 1229 of participant knowledge among males using “females” as reference; bolded, 95% CI outside
 1230 of 0.91-1.10 range (10% change or ‘clear’ difference);

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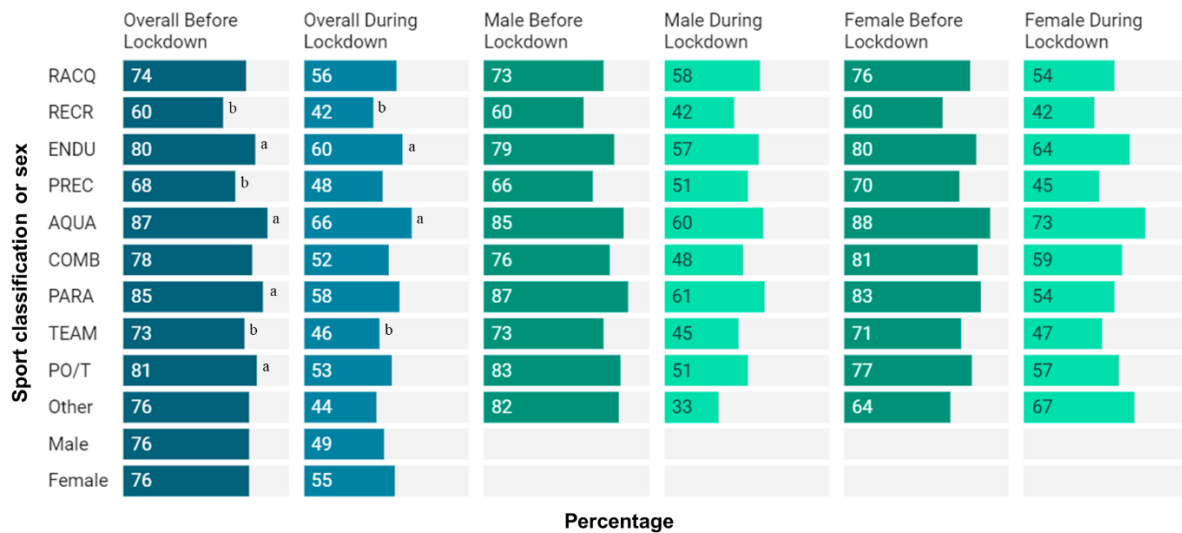
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Figure 1. Flow diagram outlining sport classification process.



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1248 **Figure 2.** Training frequency of ≥ 5 times per week based on sport classification and sex
 1249 before and during lockdown (n = 11,626).

1250 Ordered from smallest to largest reductions. %, within sex or within sports, which represent
 1251 'yes' answer relative to 'no' answer; ^a, significantly higher; ^b, significantly lower at $p < 0.05$;
 1252 Note, changes from before lockdown to during lockdown for all variables were significant (p
 1253 < 0.05) except 'Other Female'; AQUA = aquatic, COMB = Combat, ENDU = Endurance,
 1254 PARA = Parasports, PO/T = Power/technical, PREC = Precision, RACQ = Racquet, RECR =
 1255 Recreational, TEAM = Team, Other = Others.

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1269 **Figure 3.** Training duration of ≥ 60 -min per session based on sport classification and sex
 1270 before and during lockdown (n = 12,241).

1271 Ordered from smallest to largest reductions. %, within sports or within sex, which represent
 1272 ‘yes’ answer relative to ‘no’ answer; ^a, significantly higher; ^b, significantly lower at $p < 0.05$;
 1273 Note, changes from before lockdown to during lockdown for all variables were significant (p
 1274 < 0.05); AQUA = aquatic, COMB = Combat, ENDU = Endurance, PARA = Parasports,
 1275 PO/T = Power/technical, PREC = Precision, RACQ = Racquet, RECR = Recreational,
 1276 TEAM = Team, Other = Others.

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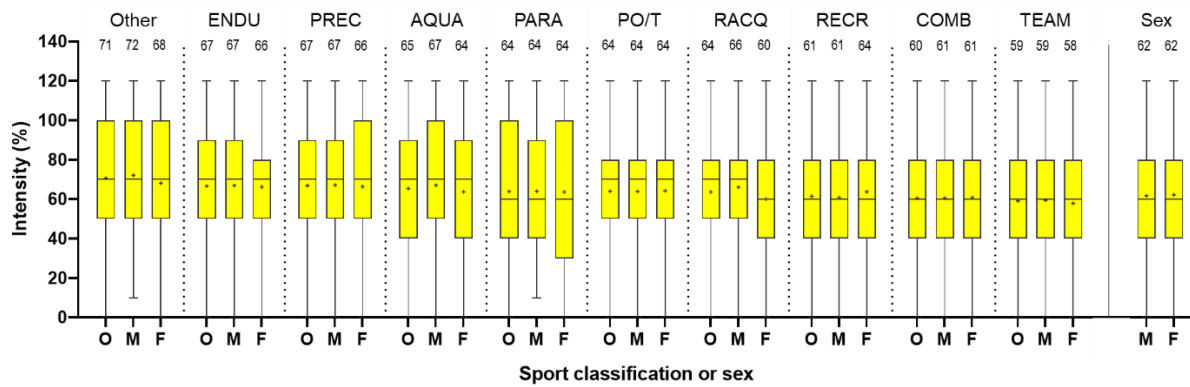
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1291 **Figure 4.** Training intensity during lockdown session based on sport classification and sex.

1292 *Question:* Do/did you maintain your pre-lockdown intensity for sports specific training
 1293 (practicing your sport) during the lockdown? Can you estimate how much in percentage?
 1294 (100% represents the same intensity as before the lockdown).

1295 Ordered from smallest to largest reductions. Data are mean \pm SD; AQUA = aquatic, COMB =
 1296 Combat, ENDU = Endurance, PARA = Parasports, PO/T = Power/technical, PREC =
 1297 Precision, RACQ = Racquet, RECR = Recreational, TEAM = Team, Other = Others; O =
 1298 overall data, M = male, F = female; note, all comparisons between male and female athletes
 1299 were significant at $p < 0.001$ (0-6% depending on sports).

1300 The whisker plot includes 5 number-summary (lowest to highest): minimum, first quartile,
 1301 median, third quartile, and maximum. The maximum or minimum number in the dataset,
 1302 respectively is shown by the upper extreme or lower extreme of the whisker/chart (excluding
 1303 outliers). Upper (third) and lower (first) quartiles, respectively are the 75th and 25th
 1304 percentiles. The median (middle of data set) is shown as a line in the center of each box; +,
 1305 mean values.

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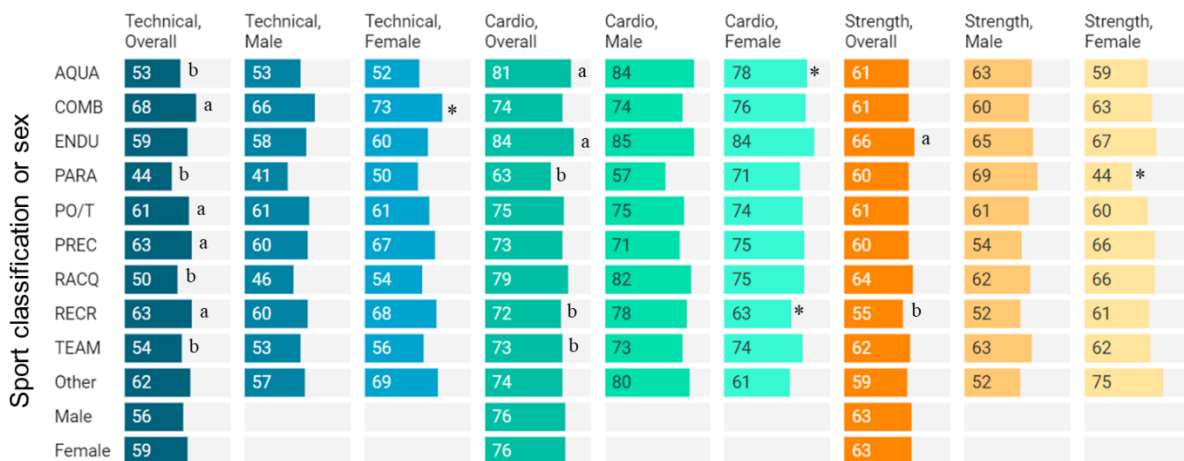
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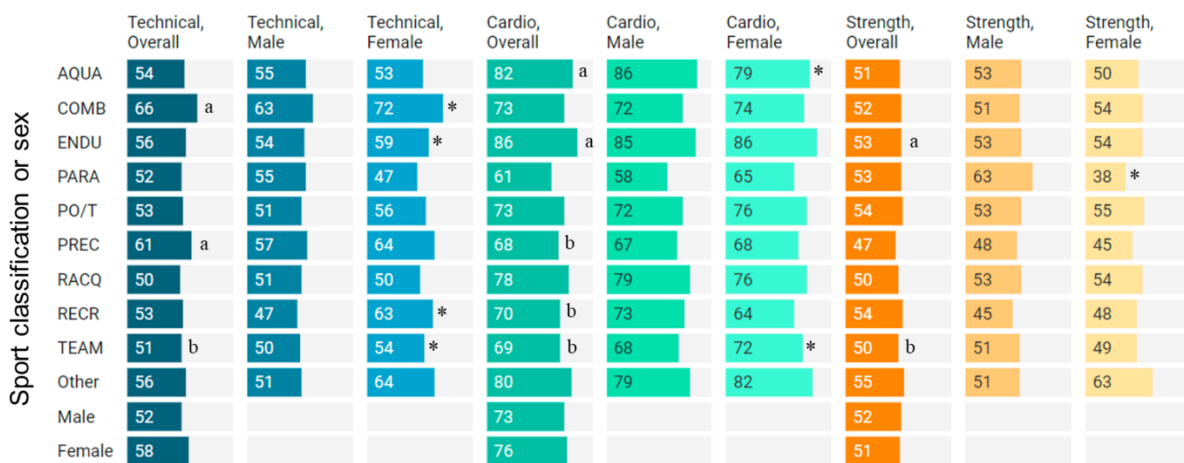
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A - Do/did you have sufficient space/access for (training):



B - Do/did you have necessary equipment to train for:



Percentage

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Figure 5. Reported practices for space/access and equipment to training based on sport classification and sex (n = 11,451).

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Question: Do/did you have (A) sufficient space/access, and (B) necessary equipment to train for:

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%, within sex or within sports, which represent ‘yes’ answer relative to ‘no’ answer; ^a, significantly higher; ^b, significantly lower at p<0.05; *, significantly higher than male; AQUA = aquatic, COMB = Combat, ENDU = Endurance, PARA = Paraspports, PO/T = Power/technical, PREC = Precision, RACQ = Racquet, RECR = Recreational, TEAM = Team, Other = Others.

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