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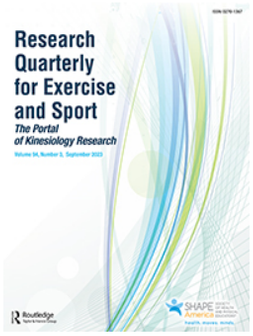

Research Quarterly for Exercise and Sport

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/urqe20

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To cite this article: Christopher Kirk (12 Oct 2023): A 5-Year Analysis of Age, Stature and Armspan in Mixed Martial Arts, Research Quarterly for Exercise and Sport, DOI: 10.1080/02701367.2023.2252473

To link to this article: https://doi.org/10.1080/02701367.2023.2252473

RESEARCH QUARTERLY FOR EXERCISE AND SPORT
https://doi.org/10.1080/02701367.2023.2252473

A 5-Year Analysis of Age, Stature and Armspan in Mixed Martial Arts

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ABSTRACT

Purpose: Athlete stature and armspan is anecdotally assumed to provide an advantage in mixed martial arts (MMA), despite an absence of supporting data. In contrast, winners of MMA bouts have been shown to be younger than bouts losers. Whilst absolute measurements of stature, armspan and armspan:stature scale (A:S) have been shown to not distinguish between winners and losers of MMA bouts, relative differences between competitors have not been analysed. This study aimed to analyse 5 years of athlete age and morphological data to replicate and expand previous studies to determine whether absolute and/or relative age and morphological variables effect winning and losing in MMA. **Methods and Results:** Bayes factor (BF>3) inferential analyses conducted on the cohort overall (n = 2,229 professional bouts), each year sampled and each individual body mass division found that only absolute (winners = 29.8 ± 4 years; losers = 30.7 ± 4.2 years) and relative age (winners = 0.82 ± 5.3 years younger than losers) differentiates between winners and losers across the whole cohort, in 4 of the 5 years, and in 4 of the 13 divisions sampled. Armspan appears to provide an advantage in heavyweight only (winners = 198.4 ± 6.6cm; losers = 196.1 ± 7.7cm), with greater A:S being a disadvantage (winners = 1.003 ± 0.022cm·cm^{-1}; losers = 1.010 ± 0.023 cm·cm^{-1}) in women's strawweight only. No variables had any effect on how bouts were won. **Conclusions:** These results confirm previous reports that the effect of athlete morphology is greatly overstated in MMA, appearing to be irrelevant in most divisions. Bout winners tend to be younger than losers, particularly in divisions displaying more diverse skill requirements.

ARTICLE HISTORY
Received 7 June 2022
Accepted 25 June 2023

KEYWORDS
Anthropometry; combat sports; morphology; performance

Mixed martial arts (MMA) is a body mass (BM) regulated combat sport in which competitors engage with each other using combined striking and grappling maneuvers to overcome their opponent over 3–5 × 3–5 minute rounds. Bouts may end due to a knockout/technical knockout (KO/TKO), submission or a judge's decision if all scheduled rounds are completed (ABC, 2018; IMMAF, 2017; Kirk et al., 2020). Accordingly, athletes require a range of technical and tactical skills to achieve success in competition (Antoniettô et al., 2019; Dal Bello et al., 2019; James et al., 2019), with these skill requirements varying between BM divisions (Kirk, 2018a; Miarka et al., 2017). Sports requiring specialized skills have been found to select athletes with specific morphological and anthropometrical proportions that enable these practitioners to more effectively perform the required actions of the event. As a result, athlete physical requirements have become increasingly specific over the preceding century with BM, stature and armspan being related to selection, success and career length in several sports (Norton & Olds, 2001). One particular morphological variable studied in recent years is the colloquially labeled "ape index," which is the scale of a person's armspan to their stature (Monson et al., 2018). Such an index would be more appropriately called armspan:stature (A:S), with this scale varying across ethnicities, countries and cultures (Popovic et al., 2013). A comparison of United States military personnel (males = 1.03 ± 0.03 cm·cm^{-1}; females = 1.02 ± 0.03 cm·cm^{-1}) to elite basketball players (1.06 ± 0.03 cm·cm^{-1}) provides an example of how inherent physical morphology may play a key role in selecting those who are likely to succeed in certain sports (Monson et al., 2018).

Having a greater armspan and/or stature than an opponent has been assumed to infer an advantage in combat sports. This is due to the belief that being taller or having longer arms would enable a competitor to strike their opponent successfully without being struck in return. Data from heavyweight boxing championship bouts support this supposition in striking only sports (Finlay & Sunderland, 2022; Han et al., 2020). In the grappling only sport of wrestling, however, stature has been found to have no effect on winning or losing (Demirkan et al., 2015). There appears to be no data available in combat sports of equivalent international standing such as taekwondo or judo. Though MMA has received more research attention in this area, the results are mixed. Kirk (2016a) reported that whilst the A:S of 474 elite MMA athletes = 1.024 ± 0.027 cm·cm^{-1}, this variable had weak negative relationships to participant rankings in isolated divisions only. Stature had mixed effects, with shorter athletes being ranked higher in the flyweight division and having more chance of winning or competing for a world championship in the featherweight division. Monson et al. (2018) found a similar A:S (1.02 ± 0.03 cm·cm^{-1}) in their MMA sample but also reported a significant positive relationship between this variable and athlete win/loss % (R^2 = .008). Richardson (2021) also demonstrated that armspan on its own is positively related to win/loss % (R^2 = .008). Though

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these analyses were completed with large samples (1,284 and 1,660 participants respectively), they each demonstrate a <1% effect of athlete morphology on performance. As such, the significance of these results potentially reflects sample size more than the practical relevance of the effect (Amrhein et al., 2017). Also, of note is the use of win/loss % as a marker of success. This variable may not be valid for comparing between participants due to the nature of MMA's competition structure, where no athlete shares the same contest schedule or opposition standard at any point in their respective careers. As such, two athletes with equal win/loss % competing in different organizations at different times, or with different bout totals would not be comparable.

To date, the only study that directly compared bout winners and losers against each other found that age was the only variable that differentiated between these groups (winners = 29.8 ± 4.3 years; losers = 30.8 ± 4.3 years; $n = 278$ bouts) with stature, armspan and A:S having no effect on who won or lost (Kirk, 2016b). There remains the possibility that the influence of morphological measurements on MMA performance may become more or less pronounced over time. Changes in the actions and activity profile of MMA bouts have altered over time owing to changes in competition rules. Such changes include alterations to the round-by-round judge scoring guidelines to place greater onus on striking rather than grappling when deciding the winner of bouts where all the scheduled rounds are completed (ABC, 2017). This has a suggested association with altered tactical approaches, including increased occurrence of the number of strikes attempted to the head and body of the opponent, and a reduction in attempted takedowns (Dos Santos et al., 2018). Given the aforementioned effect of morphology in striking only sports (Finlay & Sunderland, 2022; Han et al., 2020) it may be the case that these technical/tactical adaptations may now be revealed in differences between bout winner/loser morphology that were not present in previously reported data. Winners and losers have also only been compared in terms of their absolute morphological measurements, with the relative differences between winners and losers not yet being analyzed.

There is an absence of systematic reviews examining the effects of age or morphology on performance in MMA. A recent narrative review, however, concluded that the effect of stature or armspan differences is over-estimated, whilst there may be an influence of age both on bout outcomes and divisional rankings (Kirk et al., 2020). Given these mixed results and the absence of any between year comparison in the literature, it was determined that the between athlete comparisons of Kirk (2016b) should be replicated using data from five consecutive years. This would provide a larger sample for cohort analyses whilst also enabling any changes over time to be identified. Understanding whether there is an effect of morphology and/or age on winning or losing in MMA would enable coaches and athletes to make their pre-competition preparation more specific in terms of tactical approach and skills development. It may also improve career planning for developing MMA athletes in determining the most appropriate BM division for their physical structure.

Therefore, the aim of this study was to compare the age, stature, armspan and A:S of opponents in professional MMA bouts across a 5-year sample to further support or negate these variables having an effect on winning or losing. A secondary aim was to compare bout winners and bout losers in individual years to highlight any potential changes in the effect of athlete morphology on winning or losing over time. Analyses were conducted to test the following hypotheses: a) winners of MMA bouts are younger than bout losers; b) differences in stature, armspan and/or A:S differentiate between winners and losers of MMA bouts.

Methods

This study follows a retrospective observational cohort design and was conducted following institutional ethical approval (ER40187754). Data were recorded from international standard MMA bouts conducted between 1st January 2017 to 2nd October 2021 (inclusively) by the Ultimate Fighting Championship (UFC). All bouts were conducted under the "unified" rules of MMA as summarized previously (ABC, 2018). All UFC bouts conducted between these dates were included in the sample with the exception of those which resulted in a draw, disqualification or no contest which were excluded. Occasions where bouts were conducted outside of the BM divisions established in the unified rules of MMA (ABC, 2018), or in which one or both participants were weighed above the limit for their chosen division, were specified as catchweight and analyzed as a separate division. All instances of catchweight bouts involved male participants. Prior to competition, the stature and armspan of all competitors in UFC bouts are measured and recorded by the event promoter. Participant BM is recorded by the sanctioning body (for example the national or state licensing body) the day prior to competition in keeping with the requirements of the unified rules of MMA (ABC, 2018). Each of these measurements is then publicized on the television broadcast immediately prior to the bout itself. The following data were manually recorded from the broadcasts of each bout included in this sample for each participant: age (years), sex, division, stature (cm) and armspan (cm). Participants whose data were recorded more than once in the sample were checked for consistent reporting of all variables. Any found to be inconsistent within a participant were corrected where possible (e.g., if three data points exist in the sample with one being inconsistent) or removed (e.g., if only two data points exist in the sample so it cannot be determined which is correct). Following these criteria, a total $n = 2,229$ individual MMA bouts featuring 1,079 individual participants were included in the overall cohort. This sample included $n = 1,858$ male bouts and $n = 371$ female bouts. Participant stature and armspan were used to calculate each individual's A:S (A:S = armspan/stature), with the result being the scale of the participant's armspan to their stature ($cm \cdot cm^{-1}$). The differences between bout winners and losers was calculated for each of the following variables: age (AgeDiff), stature (StatDiff), armspan (ArmDiff) and A:S (A:Sdiff) with a positive number favoring the bout winner and a negative number favoring the bout loser. The winner of each bout was recorded, as was the method of victory (KO/TKO, submission or decision).

All bouts included in the sample, including the data used here, can be viewed via https://www.ufcfightpass.com/.

Data were checked for normality via Kolmogorov–Smirnov test ($p \geq .05$), with all variables found to be non-parametric. Inference in each of the following tests was based on the calculation of Bayes factors (BF), to provide support for either the hypothesis (BF_{10}) or the null hypothesis (BF_{01}), respectively (Quintana & Williams, 2018). Bout winners and losers were compared across the whole cohort, in each individual year, and in each division separately via Bayesian Mann–Whitney U tests with. Age comparisons were set up to test the hypothesis of bout winners being younger than bout losers. Stature, armspan and A:S comparisons were set up to test the hypothesis that bout winners and bout losers are different with no direction specified. Bayesian one sample Wilcoxon signed-ranks tests were also conducted on AgeDiff, StatDiff, ArmDiff and A:Sdiff to determine if any of these variables differed to a test value of 0. No direction was specified for StatDiff, ArmDiff or A:Sdiff. AgeDiff was set up to test the hypothesis that this variable would be <0. These were conducted for the whole cohort, in each individual year, and in each division separately. All Mann-Whitney U and Wilcoxon signed-ranks tests were conducted using a JZS Cauchy prior = .707 with location parameter = 0 (Wetzels & Wagenmakers, 2012). Rank-biserial correlation (R_x) was calculated as the effect size (Cureton, 1956).

Bayesian ANOVA using an r scale fixed effects prior = 0.5 was calculated with omega squared (ω^2) as the effect size to determine whether AgeDiff, StatDiff, ArmDiff or A:Sdiff differed in bouts that ended due to KO/TKO, submission or decision. These were calculated for the whole cohort and each year individually. For details regarding the use and interpretation of Bayesian methods of inference readers are guided toward Morey et al. (2016) and Kruschke and Liddell (2018).

The following thresholds were used for each BF: 1–2.9 = anecdotal; 3–9.9 = moderate; 10–29.9 = strong; 30 = 99.9 = very strong; ≥100 = decisive (Wetzels & Wagenmakers, 2012). Due to default priors being used, BF robustness checks were performed. Where a result was found to cross a threshold, both thresholds are reported (Wetzels & Wagenmakers, 2012). For brevity, p values are not reported for these analyses, but any result found to support a hypothesis ($BF_{10} \geq 3$) was also found to have acceptably low probability of type 1 error ($p < .05$). Any result found to have $BF < 3$ was deemed inconclusive. Ω^2 thresholds were set at: very small ≤ .01; small ≤ .06; medium ≤ .14; large > .14 (R. Kirk, 1996). R_x thresholds were set at: trivial ≤ 0.09; small ≥ 0.1; moderate ≥ 0.3; large ≥ 0.5; very large ≥ 0.7 (Cureton, 1956; Hopkins, 2002). All analyses were completed using JASP 0.16 (JASP Team, Amsterdam).

Results

Age was the only variable found to support a difference between bout winners and losers for the cohort overall (BF_{10} = 29,993, R_χ = .18). This finding also occurred in each of the years sampled with the exception of 2019 which was inconclusive (2017 BF_{10} = 93, R_χ = .15; 2018 = BF_{10} = 19, R_χ = .11; 2020 BF_{10} = 4, R_χ = .1; 2021 BF_{10} = 5, R_χ = .1) (Table 1). When examining differences within each division (Table 2), bout winners were younger than bout losers in middleweight (BF_{10} = 61, R_χ = .18), lightweight (BF_{10} = 3, R_χ = .12), featherweight (BF_{10} = 9, R_χ = .14) and bantamweight (BF_{10} = 8, R_χ = .14). The null hypothesis of no effect of age was supported

Table 1. Bout winner and bout loser descriptives by year and cohort overall.

Year	n of Bouts	Winner's Age	Loser's Age	Winner's Stature (cm)	Loser's Stature (cm)	Winner's Armspan (cm)	Loser's Armspan (cm)	Winner's A:S ($cm \cdot cm^{-1}$)	Loser's A:S ($cm \cdot cm^{-1}$)
2017	439	29.5 ± 4.1*	30.7 ± 4.2*	177.6 ± 9.5	177.6 ± 9.2	181.9 ± 11.6	181.8 ± 10.8	1.024 ± 0.027	1.023 ± 0.028
2018	469	29.7 ± 4*	30.6 ± 4.3*	177.5 ± 9	177.2 ± 9.5	182.1 ± 11.3	181.7 ± 11.6	1.026 ± 0.029	1.025 ± 0.028
2019	506	29.7 ± 3.9	30.2 ± 4.2	177.6 ± 9.5	177.2 ± 9.4	182.3 ± 11.6	181.6 ± 11	1.026 ± 0.029	1.025 ± 0.028
2020	445	30.2 ± 4.1*	30.8 ± 4.1*	177.5 ± 9.9	176.8 ± 9.7	182.3 ± 12.1	181.3 ± 11.5	1.027 ± 0.028	1.025 ± 0.027
2021	370	30.3 ± 3.7*	31.1 ± 4.4*	177.3 ± 9.4	177 ± 9.6	182.3 ± 11.1	181.9 ± 11.7	1.028 ± 0.027	1.027 ± 0.03
Overall	2,229	29.8 ± 4*	30.7 ± 4.2*	177.5 ± 9.5	177.2 ± 9.5	182.2 ± 11.5	181.6 ± 11.3	1.026 ± 0.028	1.025 ± 0.028

Nb. A:S = armspan:stature; *data support bout winners being younger.

Table 2. Bout winner and bout loser descriptives by division.

Division	n of Bouts	Winner's Age	Loser's Age	Winner's Stature (cm)	Loser's Stature (cm)	Winner's Armspan (cm)	Loser's Armspan (cm)	Winner's A:S ($cm \cdot cm^{-1}$)	Loser's A:S ($cm \cdot cm^{-1}$)
Heavyweight	181	32 ± 4.5	32.9 ± 4.9	191.1 ± 4.7	190.2 ± 6.7	198.4 ± 6.6**	196.1 ± 7.7**	1.038 ± 0.025	1.031 ± 0.025
Light-heavyweight	182	30.7 ± 4.3	30.9 ± 4.3	188.7 ± 4.4	187.9 ± 4.4	195.1 ± 6.3	193.8 ± 6.5	1.034 ± 0.026	1.031 ± 0.027
Middleweight	234	29.9 ± 3.8*	31.4 ± 4.5*	184.9 ± 4	184.3 ± 4.4	191.4 ± 6.2	190.3 ± 6.3	1.036 ± 0.029	1.033 ± 0.028
Welterweight	326	30.8 ± 3.6	31.5 ± 4	182.9 ± 4	181.8 ± 4.3	186.9 ± 5.5	187.1 ± 5.5	1.027 ± 0.025	1.029 ± 0.024
Lightweight	307	29.8 ± 3.9*	30.5 ± 4*	177.5 ± 5	177.9 ± 4.9	182.3 ± 5.6	182.2 ± 5.9	1.027 ± 0.027	1.024 ± 0.027
Featherweight	258	28.9 ± 3.5*	29.7 ± 3.4*	175.4 ± 5.2	174.9 ± 4.7	180.4 ± 5.6	179.5 ± 5.6	1.029 ± 0.028	1.026 ± 0.027
Bantamweight	241	28.7 ± 3.7*	29.8 ± 4.1*	170.9 ± 4.3	170.4 ± 4.4	174.9 ± 6.4	175 ± 6.2	1.024 ± 0.029	1.028 ± 0.031
Flyweight	109	28.2 ± 3.1	28.8 ± 3.6	166.6 ± 3.8	167.2 ± 4.3	170.8 ± 5.5	170.7 ± 5.5	1.025 ± 0.025	1.021 ± 0.024
Women's Featherweight	17	30.5 ± 2.6	30.8 ± 3.5	174.2 ± 5	172.4 ± 5.4	176.5 ± 4.5	175.9 ± 5.1	1.013 ± 0.017	1.020 ± 0.022
Women's Bantamweight	82	30.6 ± 4.3	31.3 ± 4.9	170.1 ± 4.5	168.7 ± 3.7	172.1 ± 5.2	170.4 ± 5.3	1.012 ± 0.025	1.010 ± 0.029
Women's Flyweight	134	29 ± 4.2	29.7 ± 4.1	166.8 ± 3.9	166.6 ± 4.1	168.8 ± 5.7	167.8 ± 6.6	1.012 ± 0.028	1.007 ± 0.031
Women's Strawweight	138	29.1 ± 3.6	29.9 ± 3.7	161.8 ± 4.5	161.5 ± 4.9	162.2 ± 5.1	163 ± 5.4	1.003 ± 0.022***	1.010 ± 0.023***
Catchweight	20	29.1 ± 2.7	29.7 ± 4.4	175.4 ± 6.8	175.6 ± 8	181 ± 6.7	180.5 ± 8	1.032 ± 0.026	1.028 ± 0.031

Nb. A:S = armspan:stature; *data support bout winners being younger; **data support bout winners being greater; ***data support bout losers being greater.

in light-heavyweight (BF_{01} = 6, R_χ = .03), catchweight (BF_{01} = 3, R_χ = .02), women's featherweight (BF_{01} = 3, R_χ = .03) and women's bantamweight (BF_{01} = 3, R_χ = .03). Data in all other divisions were inconclusive.

The null hypothesis of no effect of stature was supported across the whole cohort (BF_{01} = 11, R_χ = 0.02), and in each year sampled (BF_{01} = 7–13, R_χ = <.01–.05). The null was also supported in all individual divisions (BF_{01} = 3–9, R_χ = <.01–.07) apart from heavyweight, light-heavyweight, women's featherweight and women's bantamweight where data were inconclusive.

The data supported the null hypothesis of armspan not affecting winning or losing when analyzed across the whole cohort (BF_{01} = 7, R_χ = 0.03), with this pattern repeated in each year (BF_{01} = 5–13, R_χ = <.01–.05). The only division to display the effect of armspan on winning or losing was heavyweight (BF_{10} = 5, R_χ = .1). Light-heavyweight, middleweight, featherweight, women's featherweight and women's bantamweight were all found to be inconclusive, with all other division's data supporting the null hypothesis (BF_{01} = 4–11, R_χ = .01–.08).

The data supported the null hypothesis of no effect of A:S for the cohort overall (BF_{01} = 15, R_χ = 0.01) and each year (BF_{01} = 10–13, R_χ = <.01–.03). Women's strawweight was the only occurrence of the hypothesis being supported for this variable (BF_{10} = 3, R_χ = −.16), with all other division's data supporting the null hypothesis (BF_{01} = 3–8, R_χ = .03–.12) with the exception of heavyweight and women's featherweight which were inconclusive.

AgeDiff (Table 3) was found to be decisively in favor of bout winners being younger across the cohort with a small effect (−0.82 ± 5.3 years; BF_{10} = 239,368, R_χ = .18). This finding was repeated in middleweight, welterweight, lightweight, featherweight and bantamweight (BF_{10} = 4–218, R_χ = .17–.29). The null of AgeDiff being equivalent to 0 was supported at light-heavyweight, women's featherweight and women's bantamweight (BF_{01} = 3–9, R_χ = .06–.11) with all other divisions being inconclusive.

Data for StatDiff (Table 3) being greater than 0 across the cohort was inconclusive. All divisions were found to support the null hypothesis (BF_{01} = 3–12, R_χ = .03–.15) with the exception of light-heavyweight, women's featherweight and women's bantamweight which were inconclusive. ArmDiff (Table 3) was found to moderately support a trivial difference from 0 across the whole cohort (BF_{10} = 6, R_χ = .08). Heavyweight (BF_{10} = 10, R_χ = .28) and women's featherweight (BF_{10} = 3, R_χ = .11) were the only divisions to reflect this trend. Light-heavyweight, middleweight, featherweight and women's bantamweight were inconclusive, with all other divisions supporting the null (BF_{10} = 4–15, R_χ = .01–.28). The null hypothesis of A:Sdiff (Table 3) being equivalent to 0 was supported across the cohort (BF_{10} = 17, R_χ = .03) and in each division (BF_{10} = 4–9, R_χ = .04–.16) with the exception of heavyweight, women's featherweight and women's strawweight which were inconclusive.

AgeDiff (Figure 1a) was found to be different to 0 in each of the sampled years (BF_{10} = 6–205, R_χ = .17–.23) with the exception of 2019 where data were inconclusive. Data in each year sampled supported the null hypothesis of StatDiff (BF_{01} = 6–19, R_χ = .01–.09), ArmDiff (BF_{01} = 3–18, R_χ = .03–.09) and A:Sdiff (BF_{01} = 16–17, R_χ = .01–04) not being different to 0 with the exception of 2020 where data for StatDiff and ArmDiff were inconclusive (Figure 1b–d).

Neither age nor anthropometrical differences between bout winners and losers had an effect on whether the bout ended due to KO/TKO, submission or decision. The null hypothesis of no effect on bout outcome was supported for AgeDiff (BF_{01} = 15–21, ω^2 <0.01; except 2019 = inconclusive), StatDiff (BF_{01} = 7–28, ω^2 <0.01), ArmDiff (BF_{01} = 8–33, ω^2 <0.01) and A:Sdiff (BF_{01} = 4–30, ω^2 <0.01; except 2019 = inconclusive) across all years and the cohort overall (BF_{01} = 29–122, ω^2 <0.01).

Despite the absence of statistically relevant differences, some distinct trends between years did emerge. Figure 1a reveals the age difference between bout winners and losers narrowed from 2017 to 2019, before increasing again in favor of bout winners in 2020 and 2021. Differences in stature and armspan between bout winners and losers increased in favor of bout winners each year from 2017 to 2020 before decreasing back to 2018 levels in 2021 (Figure 1b,c).

Discussion

Following analyses comparing the age and morphological data of the winners and losers of 2,229 professional MMA bouts, the key result was that age is the only variable that differentiates between winning and losing competitors with minimal influence of morphology. Bout winners were found to be younger than bout losers across the whole cohort and in 4

Table 3. Age and morphological differences by division.

Division	AgeDiff (years)	StatDiff (cm)	ArmDiff (cm)	A:Sdiff (cm·cm^{-1})
Heavyweight	−0.9 ± 6.6	0.9 ± 8#	2.2 ± 9.8*	0.007 ± 0.035
Light-heavyweight	−0.2 ± 5.9#	0.8 ± 6.1	1.3 ± 8.6	0.003±.038#
Middleweight	−1.5 ± 5.5*	0.6 ± 5.9#	1.1 ± 8.6	0.003 ± 0.04#
Welterweight	−0.7 ± 5*	0.2 ± 6#	−0.2 ± 7.6#	−0.002 ± 0.034#
Lightweight	−0.8 ± 5.2*	−0.3 ± 6.4#	0.1 ± 7.8#	0.003 ± 0.038#
Featherweight	−0.8 ± 4.6*	0.5 ± 6.8#	0.9 ± 7.5	0.002 ± 0.04#
Bantamweight	−1 ± 5.3*	0.5 ± 5.9#	−0.1 ± 8.5#	−0.004 ± 0.041#
Flyweight	−0.6 ± 4.4	−0.6 ± 5.5#	0.04 ± 7.2#	0.004 ± 0.035#
Women's Featherweight	−0.3 ± 4.1#	1.8 ± 8.3	0.6 ± 7.6*	−0.007 ± 0.033
Women's Bantamweight	−0.6 ± 6.4#	1.4 ± 5.7	1.7 ± 7.3#	0.001 ± 0.036#
Women's Flyweight	−0.7 ± 4.9	0.2 ± 5.7#	1 ± 8.5#	0.005 ± 0.043#
Women's Strawweight	−0.8 ± 5	0.3 ± 6.8#	−0.8 ± 7.3#	−0.007 ± 0.033
Catchweight	−0.6 ± 6	−0.3 ± 8.1#	0.5 ± 8.9#	0.004 ± 0.05#

Nb. Data show bout winners relative to bout losers; *data statistically different to 0; #null supported of data being equivalent to 0.

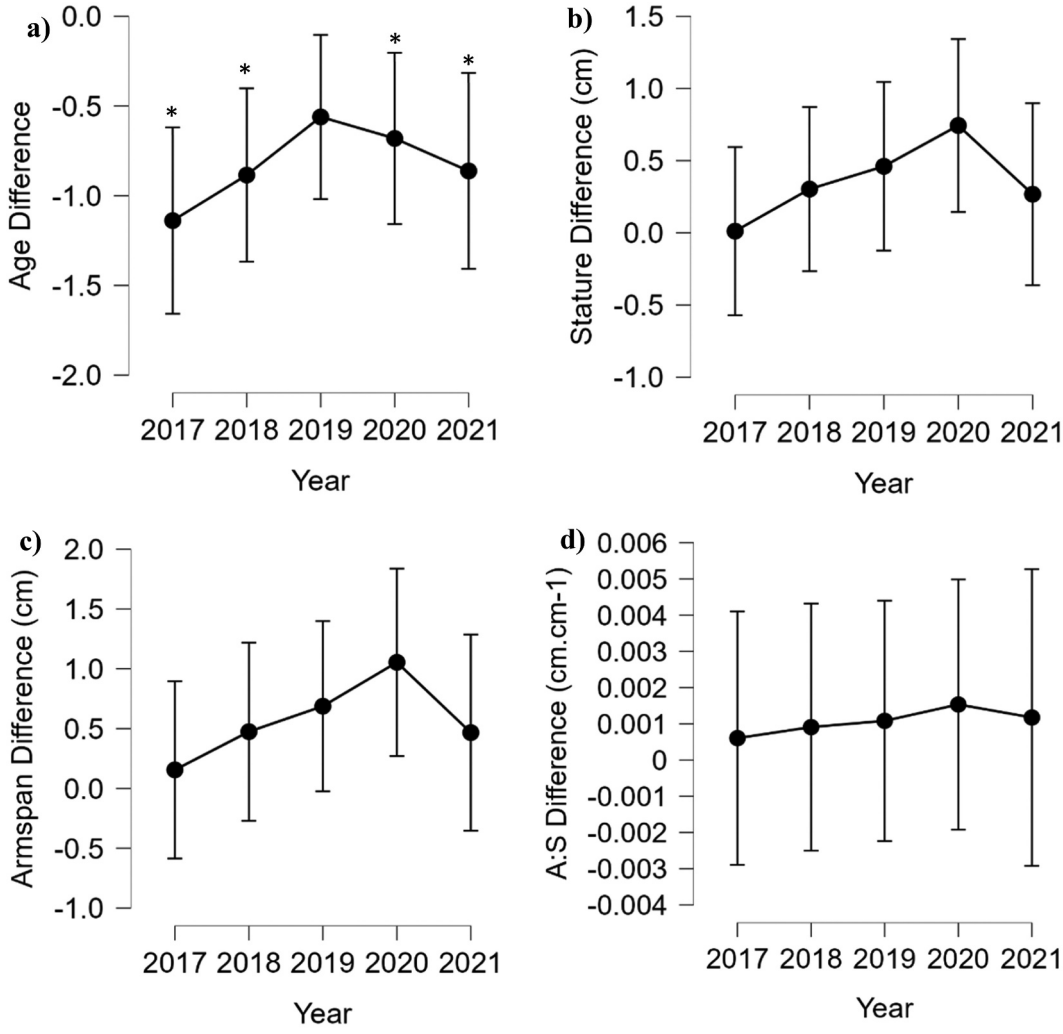

Figure 1. Mean ±95% credible interval age and morphological differences between bout winners and bout losers between years. Nb. – All plots show bout winner in comparison to bout loser; *AgeDiff statistically different to 0 in all years with the exception of 2019; No morphological variables statistically different to zero in any years; No statistically relevant morphological differences between groups or years.

out the 5 years sampled. The null hypothesis of no difference between bout winners or bout losers was supported for absolute stature, armspan and A:S. This result occurred for the cohort as a whole and all 5 years in the sample. Despite ArmDiff having a trivial difference from 0 across the cohort, the only occurrences of morphological variables differing between bout winners and bout losers were in heavyweight (greater armspan in bout winners and ArmDiff being greater than 0) and women's strawweight (greater A:S in bout losers).

Only one division displayed a positive influence of absolute morphology, with heavyweight bout winners having a greater armspan than bout losers, but with a small effect only. Athletes in this division have previously been found to have the least diverse skill requirements of all male BM categories. As bout winners and bout losers in this division are distinguished by striking actions only, with the difference in armspan between competitors partially explaining differences in significant strikes attempted and significant strikes landed (Kirk, 2018a), it stands to reason that armspan may play a role here. The more diverse contributions of standing strikes, grounded strikes and grappling actions observed in other divisions (Kirk, 2018a) seems to negate any influence armspan or stature may have on success (Demirkan et al., 2015). The only other statistically relevant result was in women's strawweight, where a greater A:S was moderately related to losing. Athletes in this division have previously been found to engage in less frequent striking actions per unit of standing time, and to perform fewer "effective" strikes than seen in other female divisions (Miarka et al., 2018). As such, any potential advantage that could be gained in striking exchanges by competitors with greater A:S appears to not be utilized at all by women's strawweight athletes.

Despite the changes in judge scoring criteria giving greater focus to striking (ABC, 2017), and this being used to explain changes in athlete technical/tactical approaches (Dos Santos et al., 2018), these results do not support the hypothesis that this provides an advantage to taller athletes or those with greater armspan. There was a trend of morphological differences between bout winners and losers increasing from 2017 to 2020, but this did not become statistically different to 0 at any point, and decreased in 2021. Even at the peak of this trend, the difference was ≤1 cm for both stature and armspan. An absolute difference of this size is therefore unlikely to provide any actual advantage in striking exchanges, which may explain why

these data do not support a difference between winners and losers. Why this trend appeared over this time period cannot be explained by these data. It could be speculated that coaches and athletes were attempting to make greater use of their perceived advantages in stature and armspan by engaging in a more striking dominant tactical approach to their bout in response to rule changes. If this was the case, it seems to have resulted in minimal effect on success. Time motion analyses would be required to understand if there was a concurrent alteration of technical/tactical actions in this period. Qualitative examinations of coach and athlete intended tactics with regards to perceived morphological differences may also prove useful for determining why this pattern emerged, and why it seems to have reverted closer to 0 over time. Currently, however, it would be recommended for competition tactical planning to disregard morphological differences between athletes given these data showing no positive effect of these variables outside of the heavyweight division.

Replicating the findings of Kirk (2016b), winners of MMA bouts were found to be younger than bout losers by ~1 year. The effects of chronological aging on performance are well documented and include reduced force (Lanza et al., 2003), VO_2max (Carrick-Ranson et al., 2013), choice reaction time (Porciatti et al., 1999) rate of force development (RFD) and impulse (Ferretti et al., 1994). Successful skill completion is associated with high RFD in the first 250–500 ms of a movement (DeWeese et al., 2015; Maffiuletti et al., 2016). Within combat sports this is characterized by a transference of force from the ground into the opponent (Lenetsky et al., 2013; Ruddock et al., 2016). Accordingly, RFD likely distinguishes between more and less successful MMA athletes (James et al., 2020) due to high impulse actions being decisive in competition (Del Vecchio et al., 2011; Kirk, 2018a). Any loss in force or RFD would therefore decrease a participant's likelihood of winning. Compounding this is the requirement to complete high impulse actions repeatedly over a maximum 9–25 mins (Kirk, 2018a). To achieve this, athletes require a well-developed VO_2max for adequate energy resynthesis within and between rounds (Bridge et al., 2014; Ovretveit, 2018). VO_2max displays a progressive decline with increased age including a marked loss in maximal capacity between the age brackets of 20–29 to 30–39 (Loe et al., 2013). As such, older athletes may fatigue earlier in a bout than younger opponents causing further decrements to their RFD and reaction times. These negative aging effects may be exacerbated by prolonged periods of sub-concussive and concussive impacts to the head in training and competition (Fares et al., 2020; Jansen et al., 2021). Such neurological trauma is related to reduced processing and psychomotor speeds in addition to impaired choice and simple reaction times (Bray et al., 2021; Mayer et al., 2015). The result may be the older athlete being slightly slower to react or less forceful than their younger opponent, and therefore less effective. These combined physiological changes may explain the confirmed finding of older athletes being less likely to win MMA bouts.

It is interesting to note that the age effect does not occur in all individual divisions. There were no statistically relevant differences in the age of bout winners or losers in heavyweight, light-heavyweight, welterweight, flyweight or any of the four women's divisions. These data cannot explain this result, but each division has been shown to have differing performance characteristics in terms of technical requirements (Kirk, 2018a; Miarka et al., 2017). These differences are also apparent between males and females (Del Vecchio et al., 2015). Of these divisions, only welterweight displays a decisive reliance on grappling actions, with success in each of the other categories being largely dependent on striking (Kirk, 2018a). It may be that age-related decrements affect grappling abilities more than striking abilities. In addition, the mean age of both bout winners and bout losers across the entire cohort was younger than the mean age of the highest 20% of the top 100 ranked MMA competitors across all male divisions, with only heavyweight displaying an age within this range (Kirk, 2018b). This suggests that older competitors do not lose on a consistent enough basis to drastically effect their divisional ranking until a certain age threshold is reached. This may also provide further evidence of a "peak performance" window where the negative effects of aging and the positive effects of technical and tactical skill mastery intersect. Each of these areas requires further research examining differences in technical skills application and success between ages to understand these findings.

Conclusions

Following analyses of the largest sample of bouts provided in the literature thus far across 5 consecutive years and each of the common BM divisions featured in MMA, age is the only variable that may distinguish between bout winners and bout losers when considered across all combined divisions. Age, however, does not appear to discriminate between female competitors or male competitors in the heavyweight, light-heavyweight, welterweight or flyweight divisions. Armspan provides a small advantage in the heavyweight division only, with no influence in any other category. Similarly, having a greater A:S only influences bout outcomes in women's strawweight where it appears to be a disadvantage. Stature does not differentiate between winners or losers in any division or across the MMA cohort as a whole. Accordingly, technical/tactical planning should prioritize skill competency and physiological fitness rather than athlete morphology.

What does this article add?

This article adds support to previously reported data that any positive effect of morphology on winning and losing in MMA is likely isolated to the heavyweight division. These data also provide a novel demonstration that this trend has not statistically changed over a 5 year period, despite rule changes giving greater weight in contest scoring to strike-based tactical approaches over grappling-based tactical approaches. Given the physiological performance requirements of the sport, age differences between athletes do differentiate between winners and losers. From a practical standpoint these data mean that athletes and coaches should avoid making technical/tactical plans based on their perceived morphological advantages. Such planning should instead be based on athlete age relative

to their opponent and the subsequent physiological performance differences that likely occur.

Limitations

As the data used in this study are those reported by event promoters, it is not known when or how these measurements were taken. These data cannot reflect the potentially different tactical approaches that MMA athletes of different morphologies may employ. Future studies are required to expand on previous work regarding the relationships between technical factors and athlete morphology to better understand any potential influence this may have (Kirk, 2018a).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethical approval

IRB Approval reference: ER40187754.

Funding

The author reported there is no funding associated with the work featured in this article.

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