

BMJ Open Grip strength among Indigenous and non-Indigenous Australian adults: a longitudinal study of the effects of birth size and current size

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To cite: Howarth T, Davison B, Singh G. Grip strength among Indigenous and non-Indigenous Australian adults: a longitudinal study of the effects of birth size and current size. *BMJ Open* 2019;**9**:e024749. doi:10.1136/bmjopen-2018-024749

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2018-024749>).

Received 11 July 2018

Revised 8 February 2019

Accepted 12 February 2019



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ABSTRACT

Objectives Indigenous Australians are born smaller than non-Indigenous Australians and are at an increased risk of early onset of frailty. This study aimed to identify the relationship between birth size, current size and grip strength, as an early marker of frailty, in Indigenous and non-Indigenous young adults.

Design Cross sectional data from two longitudinal studies: Aboriginal birth cohort (Indigenous) and top end cohort (non-Indigenous).

Setting Participants reside in over 40 urban and remote communities across the Northern Territory, Australia.

Participants Young adults with median age 25 years (IQR 24–26); 427 participants (55% women), 267 (63%) were remote Indigenous, 55 (13%) urban Indigenous and 105 (25%) urban non-Indigenous.

Outcome measures Reliable birth data were available. Anthropometric data (height, weight, lean mass) and grip strength were directly collected using standardised methods. Current residence was classified as urban or remote.

Results The rate of low birthweight (LBW) in the non-Indigenous cohort (9%) was significantly lower than the Indigenous cohort (16%) (−7%, 95% CI −14 to 0, $p=0.03$). Indigenous participants had lower grip strength than non-Indigenous (women, −2.08, 95% CI −3.61 to −0.55, $p=0.008$ and men, −6.2, 95% CI −9.84 to −2.46, $p=0.001$). Birth weight (BW) was associated with grip strength after adjusting for demographic factors for both women ($\beta=1.29$, 95% CI 0.41 to 2.16, $p=0.004$) and men ($\beta=3.95$, 95% CI 2.38 to 5.51, $p<0.001$). When current size (lean mass and body mass index [BMI]) was introduced to the model BW was no longer a significant factor. Lean mass was a positive indicator for grip strength, and BMI a negative indicator.

Conclusions As expected women had significantly lower grip strength than men. Current size, in particular lean mass, was the strongest predictor of adult grip strength in this cohort. BW may have an indirect effect on later grip strength via moderation of lean mass development, especially through adolescence and young adulthood.

INTRODUCTION

Grip strength in adulthood is a measure of muscle strength in the arm and a marker of future morbidity and mortality.^{1–5} Lowered

Strengths and limitations of this study

- Directly collected data, including detailed body composition, using standardised methods.
- Inclusion of previously understudied, remote and very remote Indigenous Australians.
- Information available in an under-reported, transitional age group; young adulthood.
- Limited physical activity data available.
- Limited participant numbers when stratified by gender, indigeneity and location.

grip strength in the elderly has been associated with a decrease in perceived quality of life,⁴ daily functionality,⁶ increased frailty^{5, 7} and heightened risk of all-cause mortality.⁸ A large prospective cohort study has linked grip strength in adolescence to increased risk of cardiovascular disease, cancer and poor mental health outcomes, including suicide in early adulthood.⁹

Muscle strength in adulthood is influenced by gender, skeletal size, lean mass and physical activity.^{10–12} Previous research has indicated the divergence in grip strength between genders to be predominantly explained by the differential growth, particularly of muscle mass, through adolescence.¹³ In addition to these factors, several epidemiological studies have drawn associations between birth weight (BW) (as a surrogate for intrauterine growth),^{7, 14, 15} early growth^{16, 17} and later grip strength, independent of later size or physical activity. However, the majority of these studies have analysed grip outcomes in mid to late adulthood, and thus it is uncertain if BW leads to reduced peak strength occurring in early adulthood, or a faster decline in grip strength occurring thereafter. Fetal growth restriction, defined as babies in the 10th percentile for gestational age (GA), has

been shown to have significant influences on muscle metabolism and growth through childhood and into adulthood.^{18–20}

Indigenous Australians have significantly higher rates of low birthweight (LBW) babies,²¹ lower life expectancies than non-Indigenous Australians,²² and they appear to become frail at an earlier age.²³ Populations in Australia living rural or remote do not have the same healthcare access, nutritional, educational or employment opportunities as comparable urban populations.^{22,24} These populations have high mortality rates and lower life expectancies, the lowest of which is found in remote Northern Territory (NT).²⁴ Of the 69 000 Indigenous people residing in the NT approximately four out of five live in remote/very remote communities and outstations according to Australian geographic standard classification.²⁵ Indigenous Australians face many challenges across the life course which may exacerbate the influence of low BW on later health outcomes compared with a non-Indigenous population. Furthermore, the challenges associated with remote or rural living may further exacerbate the effects of low BW.

This study examines the associations of birth size, current size and grip strength in remote Indigenous, urban Indigenous and urban non-Indigenous young adults in the NT.

METHODS

Participants

Data are presented from two distinct but complementary longitudinal cohorts based in Darwin, NT: the Aboriginal Birth Cohort (ABC) and the non-Indigenous Top End Cohort (TEC).

The recruitment of the ABC has been described in detail elsewhere.²⁶ In brief, the ABC is a prospective study of 686 babies born to Indigenous mothers (a representative sample of the 1238 eligible babies) recruited at Royal Darwin Hospital (RDH) between January 1987 and March 1990 to a mother recorded as Indigenous in the Delivery Suite Register. RDH is the main hospital for an area covering 120 000 km² of the 'Top End' of the NT and, at the time, >90% of pregnant Indigenous mothers from this region came to the RDH to deliver their babies.²⁷ The TEC comprises 196 non-Indigenous participants recruited and assessed between 2007 and 2009 (average age 18.3 years). Eligibility criteria were birth in Darwin to a non-Indigenous mother between 1987 and 1991 (ie, age matched to the ABC) and still living in Darwin at the time of recruitment.²⁸

A combined follow-up of ABC and TEC participants occurred between 2013 and 2015 at a mean age of 23.8 years. Indigenous participants reside in over 40 urban and remote communities across the NT. Remote communities vary in population size from 200 to 2000 people, with many small family groups living in outstations (<50 people).

Data collection

Birth data, including BW and GA, was recorded at recruitment for ABC participants, and extracted from hospital records for TEC participants. Face-to-face assessments of participants were conducted by trained researchers between 2015 and 2016. Grip strength was assessed using a hand-held dynamometer (Smedley, S dynamometer, TTM, Tokyo, 100 kg) following a standardised protocol and recorded in kilograms. Participants had a maximum of three attempts for left and right hands, alternating between trials, with the maximal value, irrespective of hand, used in the analyses.

Anthropometric measures were taken with participants in light clothing and barefoot. Height was recorded on hard, flat flooring to the nearest millimetre using a portable stadiometer. Weight was measured to the nearest 0.1 kg with a digital electronic scale (TBF-521, Tanita Corporation, Illinois, USA) and lean mass to the nearest 0.1 kg through bioimpedance measure from the same scale. Body mass index (BMI) was calculated using the standard formula (kg/m²). Physical activity was self-reported and categorised as either active (≥5 hours physical activity/week) or inactive (<5 hours physical activity/week).

Statistical analyses

Statistical analysis was performed in STATA 14.2 (College Station, TX). Participants were included if they had complete data (including at least two recorded grip strength attempts from the same hand). Residence was classified as living 'remote' (remote community with an Aboriginal council) or 'urban' (Darwin & rural towns) at the date of collection. Quantile regression was used to determine differences between medians for GA, linear regression to determine differences between means for BW, height, weight, lean mass and BMI, and proportions test to determine difference in proportion engaging in physical activity. Each test was stratified by gender, Indigenous status and location. Univariate linear regression was used to explore the relationship between grip strength, gender, Indigenous status and location. Multivariate regression adjusted the effect of birth size and current size for gender, Indigenous status and location. Continuous variables for multivariate regressions were standardised among women and men respectively, and coefficients reported as SD increases.

Participant involvement

Participants were involved in the development of methods related to this study by cohort reference groups. Results of this study are to be disseminated to the participants via private Facebook groups of both cohorts, and on the study website.

RESULTS

Of the 576 participants seen (55% women), 89 (16%) were excluded due to having no (n=88) or only a single

Table 1 Descriptive overview of cohort characteristics

	Remote Indigenous	Urban Indigenous	Urban non-Indigenous
Women	n=145	n=24	n=66
Gestational age (weeks, IQR)	39 (39, 40)	39 (38, 39)	40 (40, 40)
Birth weight (g)	2991.4 (2902.5–3080.2)	2695.9 (2462.5–2929.2)	3288.4 (3174.1–3402.7)
Age (years)	25.1 (24.9–25.3)	25.2 (24.7–25.7)	23.6 (23.2–23.9)
Height (cm)	161.7 (160.8–162.6)	162.1 (159.9–164.2)	166.4 (164.6–168.3)
Weight (kg)	63.3 (60.3–66.2)	69.7 (63.6–75.8)	66 (62–69.9)
Lean mass (kg)	41.4 (40.5–42.3)	43.8 (42.1–45.6)	45.7 (44.5–46.9)
Body mass index (kg/m ²)	24.2 (23.1–25.3)	26.5 (24.2–28.8)	23.7 (22.5–24.9)
Physical activity (%)	37.23 (29.3–48.8)	29.2 (9.6–48.8)	60.6 (48.5–72.7)
Grip strength (kg)	21 (20.1–22)	20.5 (18.5–22.4)	23.2 (21.8–24.7)
Men	n=122	n=31	n=39
Gestational age (weeks, IQR)	39 (39, 40)	39 (39, 40)	40 (39, 40)
Birth weight (g)	3098.7 (2992.2–3205.3)	3267.1 (3048.2–3486)	3314.7 (3137.3–3492.2)
Age (years)	25.4 (25.2–25.6)	25.5 (25–25.9)	24.1 (23.6–24.6)
Height (cm)	173.6 (172.3–174.8)	177.2 (174.2–180.1)	179.9 (176.5–183.2)
Weight (kg)	68 (64.7–71.2)	89.6 (79.5–99.6)	82.6 (77.9–87.3)
Lean mass (kg)	54.4 (52.7–56)	64.4 (60.3–68.5)	65.3 (62.4–68.1)
Body mass index (kg/m ²)	22.5 (21.5–23.4)	28.2 (25.6–30.9)	25.5 (24.2–26.9)
Physical activity (%)	82 (75.1–88.9)	58.1 (39.7–76.5)	66.7 (51.2–82.1)
Grip strength (kg)	36.7 (35–38.4)	47.3 (43.4–51.3)	45 (42.1–47.8)

(n=1) grip strength value recorded, 53 (9%) had no lean mass measure and 7 (1%) had no GA recorded. Complete data were available on 427 participants, the majority were remote residing Indigenous 267 (63%), with the remainder urban Indigenous 55 (13%) and urban non-Indigenous 105 (25%), reflective of the available cohort (table 1). Median age was 25 years (IQR 24–26).

Birth size

Indigenous participants were born earlier (−0.9 weeks, 95% CI −1.16 to −0.64, p<0.001) and smaller (−261.62 g, 95% CI −385.33 to −137.9, p<0.001) than non-Indigenous, with 15.5% born <2500 g compared with 8.6% of non-Indigenous participants (−7%, 95% CI −13.6 to −0.2, p=0.0364). On stratifying by gender, this significant difference remained for women (−0.9 weeks, 95% CI −1.26 to −0.54, p<0.001 and −338.99 g, 95% CI −490.1 to −187.89, p<0.001), with Indigenous men born earlier than non-Indigenous men (−0.9 weeks, 95% CI −1.34 to −0.46, p<0.001) but no significant difference in BW evident (−181.9 g, 95% CI −389.7 to 25.9, p=0.085). No differences in birth characteristics were seen between remote and urban residing Indigenous men, however, remote residing Indigenous women were born significantly later (0.8 weeks, 95% CI 0.1 to 1.5, p=0.025) and larger (295.47 g, 95% CI 59.29 to 531.65, p=0.015) than urban Indigenous women.

Current size

Indigenous participants were significantly shorter (−3.73 cm, 95% CI −5.82 to −1.64, p=0.001) and had less muscle mass (−4.28 kg, 95% CI −6.71 to −1.85, p=0.001) than non-Indigenous participants, however no difference in BMI or the proportion engaging in physical activity was seen. When stratified by gender, Indigenous women were shorter (−4.7 cm, 95% CI −6.44 to −2.96, p<0.001) and had less muscle mass (−3.99 kg, 95% CI −5.44 to −2.54, p<0.001). Indigenous men were shorter (−5.59 cm, 95% CI −8.44 to −2.75, p<0.001), lighter (−10.24 kg, 95% CI −17.62 to −2.85, p=0.007), had less lean muscle mass (−8.86 kg, 95% CI −12.4 to −5.32, p<0.001) and engaged in less physical activity (−24.5, 95% CI −10.7 to −38.3, p<0.001) than non-Indigenous men. Remote residing Indigenous men were significantly shorter (−3.59 cm, 95% CI −6.47 to −0.71, p=0.015), lighter (−21.62 kg, 95% CI −29.75 to −13.49, p<0.001), had less lean mass (−10 kg, 95% CI −13.78 to −6.22, p<0.001) and a lower BMI (−5.78 kg/m², 95% CI −8 to −3.56, p<0.001) than their urban counterparts.

Grip strength

Indigenous women (−2.27, 95% CI −3.89 to −0.66, p=0.006) and men (−6.15, 95% CI −9.84 to −2.46 p=0.001) had significantly lower grip strength than their non-Indigenous counterparts. Among Indigenous men, location was a significant influence, however this was not seen in

Table 2 Standardised coefficients and p values for factor effects on grip strength

	Women			Men		
	β^*	95% CI	P value	β^*	95% CI	P value
Indigenous status						
Non-Indigenous	Reference category					
Indigenous	-2.27	-3.89 to 0.66	0.006	-6.15	-9.84 to 2.46	0.001
Location						
Urban	Reference category (Indigenous participants only)					
Remote	0.56	-1.86 to 2.97	0.648	-10.64	-14.6 to 6.69	<0.001
Physical activity						
Inactive	Reference category					
Active	2.55	1.09 to 4.00	0.001	-1.93	-5.44 to 1.59	0.281
Gestational age	0.66	-0.08 to 1.39	0.08	0.16	-1.37 to 1.69	0.834
Birth weight	1.43	0.71 to 2.15	<0.001	3.6	2.16 to 5.04	<0.001
Lean mass	2.82	2.18 to 3.47	<0.001	7.69	6.62 to 8.75	<0.001
BMI	1.72	1.01 to 2.42	<0.001	4.95	3.59 to 6.3	<0.001
Height	2.44	1.77 to 3.11	<0.001	6.11	4.86 to 7.37	<0.001
Weight	2.44	1.78 to 3.11	<0.001	6.43	5.2 to 7.65	<0.001
Model 1 (Adjusted for Indigenous status, location, gestational age and physical activity)						
Birth weight	1.41	0.50 to 2.31	0.002	3.98	2.41 to 5.55	<0.001
Lean mass	2.86	2.19 to 3.53	<0.001	7.25	6.05 to 8.46	<0.001
BMI	1.88	1.20 to 2.56	<0.001	3.92	2.50 to 5.35	<0.001
Height	2.37	1.68 to 3.07	<0.001	5.37	4.12 to 6.62	<0.001
Model 2 (Adjusted for Indigenous status, location, gestational age, physical activity, birth weight, lean mass and BMI)						
Birth weight	0.49	-0.34 to 1.32	0.248	0.45	-0.87 to 1.95	0.453
Lean mass	4.15	2.82 to 5.47	<0.001	8.26	6.45 to 10.06	<0.001
BMI	-1.52	-2.74 to 0.29	0.016	-1.71	-3.31 to 0.11	0.036

* β values for continuous variables are standardised such that each unit represents a SD increase. BMI, body mass index.

women (0.56, 95% CI -1.86 to 2.97, $p=0.648$). Remote Indigenous men had a 10.6 kg deficit (95% CI -14.6 to -6.69, $p<0.001$) in maximal grip strength compared with urban Indigenous men. Physical activity did not show any association to maximum grip strength (table 2).

Birth size and current size associations with grip strength

Grip strength was significantly and positively associated with BW in univariate regression and on adjusting for demographic factors and GA in both women and men (table 2). A one SD increase in BW was associated with 1.43 kg (95% CI 0.7 to 2.2) and 3.6 kg (95% CI 2.2 to 5.0) increases in maximum grip strength in women and men respectively (table 2). Current size factors of lean mass, BMI and height were also significantly and positively associated after adjustment, with lean mass having the greatest effect on grip strength.

The influence of BW on grip strength was attenuated in the full model, with further adjustment for current size. Inclusion of BMI as opposed to height showed a slightly stronger model. Among women, lean mass, BMI

and physical activity were significant factors, while among men only lean mass and BMI remained significant. The influence of lean mass was significantly stronger in men (8.3 kg, 95% CI 6.5 to 10.1) compared with women (4.2 kg, 95% CI 2.8 to 5.5). BMI showed a significant negative association with grip strength in women (-1.52, 95% CI -2.74 to -0.29, $p=0.016$) and men (-1.71, 95% CI -3.31 to -0.11, $p=0.036$), with a similar influence between genders.

The full model accounted for 32% and 54.8% of variation for women and men, respectively. Indigenous status and location appeared to have an interactive effect which differed between women and men (figure 1). In comparison to urban non-Indigenous women, remote Indigenous women had greater grip strength. Among men, the urban Indigenous group had greater grip strength.

DISCUSSION

In this cohort, as expected women displayed significantly lower grip strength than their male peers. Overall,

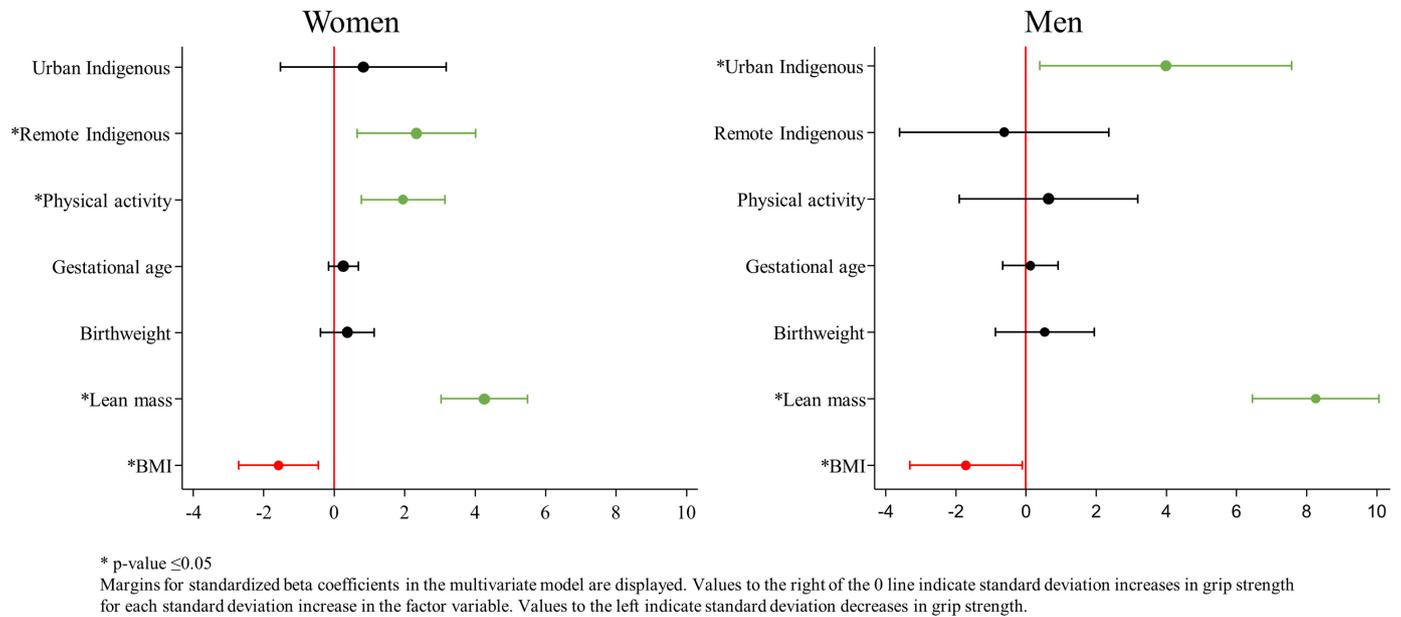


Figure 1 Standardised margins of effects on adult grip strength. BMI, body mass index.

Indigenous participants had a lower grip strength than non-Indigenous; however the effect of living remote or urban differed between women and men. Remote Indigenous men recorded lower grip strength than their urban Indigenous peers, while among women there was no significant difference.

The mean grip strength for women, regardless of if remote Indigenous (21.2 kg, 95% CI 20.34 to 22.1), urban Indigenous (20.5 kg, 95% CI 18.5 to 22.4) or non-Indigenous (23.2 kg, 95% CI 21.8 to 24.7), was significantly lower than reported Australian values for women (30 kg \pm 7 kg).²⁹ Despite being much younger, women in the current cohort recorded grip strength values similar to those previously recorded for women aged 60–69 years.²⁹ Among men, both urban Indigenous (47.3 kg, 95% CI 43.4 to 51.3) and non-Indigenous (45 kg, 95% CI 42.1 to 47.8) participants displayed similar values to previously reported values for Australian men (47 kg \pm 9.5), however remote Indigenous men (36.7 kg, 95% CI 34.9 to 38.4) were significantly weaker.²⁹

Differing grip strength values have been recorded across ethnicities,^{30 31} with Asian countries displaying significantly lower values than western countries. The population in urban Darwin is highly multicultural, with migrants drawn largely from south Asian countries.³² In the current study this ethnic ancestry may have led to the lowered grip scores seen in the urban non-Indigenous participants.

Indigenous Australians, especially those living remote, have been described as having characteristics similar to those of populations in developing regions internationally. Factors such as access to food, rates of infection and chronic disease, and lifestyle risk factors such as smoking, alcohol and physical inactivity may have contributed to the lower grip strength seen.³³ Adedoyin *et al* reported on grip strength among Nigerian men and women.³⁴

Nigerian men aged 20–29 displayed similar maximal grip strength (39 kg \pm 10.9 kg) to the remote residing Indigenous men in this study (36.7 kg). In the same study, Nigerian women aged 20–29 recorded significantly higher grip strength (25.1 kg \pm 6.4) than both remote (21.3 kg) and urban (20.5 kg) Indigenous women in the current study. Another study conducted in Malaysia reported grip strength of 17.1 kg (\pm 5 kg) and 32.3 kg (\pm 7.8 kg) for women and men, respectively.³⁵ Differing methodologies and equipment limit comparability between the studies, however it appears grip strength of Indigenous Australian women and remote residing Indigenous men in this cohort is similar to that seen in developing countries.

The gender differences noted for the influence of location are likely due to the difference in muscle fibre composition between women and men. Men typically display a significantly greater proportion of type II muscle fibres than women.³⁶ Studies in animal models suggest that type II muscle fibres experience greater burden from food deprivation than type I muscle fibres.^{37 38} Thus in adverse environments, type II muscular atrophy and resultant strength decline would effect men to a greater degree than women.

Although BW showed significant associations with grip strength in this cohort, it was attenuated after adjusting for current size. Several previous studies have identified such an influence of BW on grip strength, which remained after adjusting for height and weight.^{16 39 40} In previous research, when an adjustment was made for lean mass the association between grip strength and BW disappeared in men, and was significantly attenuated in women.³⁷ Furthermore, BW was significantly and positively correlated with adult lean mass. Adolescents born LBW have shown decreased odds of engaging in leisure time physical activity which may be the mechanism of reduced lean mass in adulthood.³⁹ However, in the

current study a separate analysis found non-significantly heightened odds of physical activity among LBW participants. Jensen *et al*⁴¹ described a decreased proportion of type II muscle fibres in young adults born LBW thereby decreasing their anaerobic capacity, and potentially lower grip strength.⁴⁰

Adult lean mass was a stronger predictor of grip strength than BMI, accounting for 30% and 50% of variation in grip strength for women and men, respectively. For both women and men increasing BMI, when adjusted for lean mass, was associated with a decrease in grip strength. In this case, due to the adjustment of lean mass, the increased BMI is a function of increased adiposity, which may be the result of decreased physical activity. Yliharsilä *et al*³⁹ described a significant negative association between grip strength and per cent body fat, corroborating this theory.³⁷ Individuals who are sedentary have been shown to have lower grip strength compared with active peers, while among the elderly, increased BMI has been associated with decreased grip strength.^{29 34 42}

Grip dynamometry is a cheap, efficient and reliable test which can be fairly easily incorporated into clinical environments.^{43 44} Many participants in this study had grip strength values well below the norm for their age group which is concerning given the associations between grip strength and risk of early sarcopenia,^{16 30 45} limited mobility and frailty,⁴⁶ type 2 diabetes,³¹ and premature mortality. It has also been associated with poor mental health outcomes, including suicide.⁹ Early identification in primary healthcare gives the opportunity for early interventions. Young adults respond faster and to a relatively greater degree to exercise interventions than older adults. Furthermore, grip strength may serve as a more visible motivator for lifestyle change compared with triglycerides or glucose levels, and testing can be more palatable allowing for consistent progress checks. The significant influence of location among male participants is a novel result and may warrant further attention for remote healthcare practitioners.

Limitations

The main limitation of this study is the relatively small participant numbers that may have reduced the power to detect small associations. However, several significant associations were seen. The unequal distribution between remote and urban participants, while affecting the power of results, is representative of the Indigenous population distribution in the NT.

The influence of the interviewer on outcomes has previously been listed as a confounder.^{4 16 17} In a separate analyses introducing an adjustment for the interviewer the difference in this cohort was found to be negligible ($\beta=0.001$).

CONCLUSION

Remote Indigenous participants had significantly lower grip strength than their urban peers, which may place

them at an increased risk of early morbidity and mortality. Remote Indigenous men displayed the typical antecedents of low grip strength; that is being born small and remaining smaller on all measures of current size. The major difference in strength, birth size and current size between remote and urban young adults, particularly in men, highlights the need for specialised health programmes tailored to region and cultural context.

Acknowledgements We wish to acknowledge past and present study teams, in particular Dr Susan Sayers, founder of the ABC study. We especially thank the young adults belonging to the Aboriginal Birth Cohort and Top End Cohort and their families and community for their cooperation and support and all the individuals who helped in the urban and rural locations.

Contributors GS and BD were involved in the concept and design of the study and acquisition of data, TH was responsible for analyses and interpretation of data and drafted the manuscript, all authors revised article critically for important intellectual content, and provided final approval of the version submitted.

Funding This work was supported by the National Health and Medical Research Council of Australia (Project Grant APP1046391).

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval All participants provided written informed consent to participate in this study, and all procedures were approved by the Human Research Ethics Committee of the Northern Territory Department of Health and the Menzies School of Health Research, including the Aboriginal Ethical Sub-committee which has the power of veto (ABC Reference no. 2013–2022 and TEC Reference no. 2013–1986).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement All data are stored confidentially and although not freely available in the public domain, is available on request and specific proposals for collaboration are welcomed.

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