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National Variations in CAG Repeats of Men's Androgen Receptor Gene: A Tabulated Review

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As the mediator of androgen actions, the androgen receptor (AR) plays a central role in establishing both physical and behavioral sex differences. The AR gene contains a CAG repeat polymorphism that is related to the strength of androgen actions on target tissues and that is correlated with various health-related conditions, especially prostate cancer and infertility. Some studies have also linked the number of AR CAG repeats with behavioral and mental health factors. The present study provides a tabulated summary of the average number of AR CAG repeats for males according to the countries in which each study was conducted, thereby allowing future research to correlate national average AR CAG repeats with national variations in physical, medical and behavioral traits. Findings are summarized in two tables. The first table lists results from each of 187 studies of a total of 57,826 research participants according to the country in which each study was conducted. In the second table, the results from the first table are condensed down to the average number of AR CAG repeats for each of the 78 countries from which samples were drawn.

Key Words: Androgen receptor, Polymorphism, Countries, Data, Review

Androgens, and in particular the hormone testosterone produced by the testes, are major actors in sexually dimorphic developmental processes. In addition to the development of male genitalia and other physical sex differences, they also produce behavioral sex differences in animals (Ligon et al., 1990; Preston et al., 2012) and humans (Josephs et al., 2006; Sellers, Mehl & Josephs, 2007). The cellular actions of testosterone and other androgens are mediated by the androgen receptor (AR), a protein that binds to regulatory sites of many genes and either stimulates or, sometimes, represses the transcription of the genes when testosterone or some other androgen is bound to it (Chamberlain, Driver & Miesfeld, 1994). Without androgen receptors, testosterone cannot regulate gene expression and therefore cannot have effects on bodily functioning. Males whose androgen receptor gene is non-functional do not develop male genitalia. Their physical appearance and psychosocial development are female. In other words, regardless of how much testosterone an individual may produce, the AR gene determines the extent to which testosterone is able to actually alter intracellular activity (Batrinos, 2012; Ding et al., 2004; Meyer et al., 2010).

In humans, the AR gene comes in many forms, called *alleles*. The best studied alleles are those involving a CAG repeat sequence that encodes a polyglutamine tract near the amino end of the androgen receptor. This CAG repeat has different lengths in different people. In humans, the number of AR CAG repeats ranges from as few as 9 to as many as 36, but population averages are typically between 17 and 24 (Chamberlain et al., 1994; Hsiao et al., 1999; Irvine et al., 2000; La Spada et al., 1991). Individuals with higher numbers of AR CAG repeats will normally have diminished testosterone action on cellular functioning, effectively making males with high AR CAG repeats less masculine regarding most sexually dimorphic traits when compared to males with fewer AR CAG repeats (Loehlin et al., 2004; Simanainen et al., 2011).

Why Study AR CAG Repeats?

Several diseases have been found to be statistically associated with the number of AR CAG repeats. In men, these primarily include prostate cancer, which appears to be inversely correlated with the number of repeats (meta-analyses: Gu et al., 2012; Qin et. al., 2017; Weng et al., 2017), and infertility which is positively correlated (meta-analysis: Mobasseri et al., 2018; Xiao et al., 2016). Also, some research has found an inverse relationship between the number of AR CAG repeats and male pattern baldness (Ellis et al., 2007; Hillmer et al., 2005).

Among women, associations with the number of AR CAG repeats are more difficult to assess because females have two X chromosomes, and therefore two AR genes (albeit one of which is usually non-functional). Despite this qualification, inverse correlations have been found between AR CAG repeats and the incidence of breast cancer (Hao et al., 2010), at least among women of European descent (Mao et al., 2015).

For both sexes, AR CAG repeats have also been implicated as causing skin-related illnesses such as acne and hirsutism (Sawaya & Shalita 1998; Yang et al., 2009). Other diseases that are possibly associated with the number of AR CAG repeats are migraines, Alzheimer's disease, and spinal-muscular atrophy (Kennedy's disease) (review: Singh, Singh & Thangaraj, 2007).

Complexity in research findings on relationships between AR CAG repeats and various health-related traits have come from evidence of a substantially increased risk of gallbladder cancer among men with high AR CAG repeats, while women with the greatest number of repeats had a significantly *lower* risk of the same form of cancer (meta-analysis: Meyer et al., 2010). Furthermore, research on the association between AR CAG repeats and male testicular cancer suggests that the relationship is curvilinear (meta-analysis: Jiang et al., 2016).

Behavioral and mental health factors have also received research attention in connection with AR CAG repeats. For example, relatively short AR CAG repeat numbers have been found associated with psychoticism (Turakulov et al., 2004). Another study confirmed this pattern for adolescent females but not for adolescent males (Loehlin et al., 2005). Along similar lines, one study indicated that short AR CAG repeats were associated with impulsive-disinhibited personality traits (Aluja et al., 2011), and another found short AR CAG repeats associated with extraversion (Lukaszewski & Roney, 2011). AR CAG repeat numbers were recently found positively correlated with sexual jealousy (Lewis et al., 2018).

Along experimental lines, a study of college students reported that low AR CAG repeat males exhibited a rise in testosterone within a half hour or so after socially interacting with a young woman. This pattern did not occur among males with high numbers of repeats, and no AR CAG-related differences were found when males interacted with other males (Roney, Simmons & Lukaszewski, 2010). These findings coincide with evidence that adding AR CAG repeats seems to curtail the body's ability to synthesize and release testosterone (Campbell et al., 2009; Chamberlain, Driver & Miesfeld, 1994).

Some research has also implicated AR CAG repeats in the study of criminality, especially violent forms. One study of imprisoned males reported that conviction for violent offenses was inversely correlated with AR CAG repeat length (Rajender et al., 2008). Another study found no significant difference between the AR CAG repeats among violent criminals and control males, but did report a higher incidence of unusually short AR CAG repeats among the violent offenders in their sample (Cheng et al., 2006).

The Present Investigation

The above leads one to suspect that AR CAG repeats could play a substantial role in influencing many aspects of human health and well-being. Studies of behavioral effects are much less numerous than those dealing with health, but these studies also point toward the potential for valuable insights to be gained by linking AR CAG functioning with behavior.

All of the studies conducted so far on male AR CAG repeats have been limited to comparing samples of individuals. We are inclined to suspect that relationships at ecological levels of analysis may also be worth pursuing. In other words, countries that have males with unusually high or low AR CAG repeats could, as a result, also exhibit unusually high or low rates of certain diseases or behavioral patterns.

To make it possible to conduct ecological-level analyses, the present investigation was undertaken to compile all of the national data on average AR CAG repeats for males that could be located. Our search was limited to males for three inter-related reasons: First, most AR CAG repeat studies conducted so far have been among males. Second, AR CAG repeats appear to primarily affect testosterone, a hormone that is much higher in males than in females. And, third, males have just one X chromosome whereas females have two.

Method

Using Google Scholar as our search platform, we scoured the scientific literature for studies in which average length of AR CAG repeats among males was reported. This search located 187 studies, which are listed in Table 1.

These studies reported different types of averages. If the average AR CAG repeats reported was the mean, this was the one put in Table 1. Instead of the mean, some studies only reported either the median or the mode. In these cases, we preferentially recorded the median and, when the median was not reported but the mode was, the mode appears in Table 1. Finally, four studies provided two more or less evenly peaked modes (and no mean or median) in graphic form. For these four studies, the mean of the two modes was calculated and presented in Table 1 as a single average.

Another methodological comment has to do with studies that compared a clinical sample (e.g., males with prostate cancer) and a sample of control males. In these studies, we only included the controls. On the other hand, a substantial number of studies were of a surveying nature. For these studies, the average for the entire sample was utilized.

Finally, it should be noted that several of the studies reported drawing their samples from a single large city within a country, rather than from the country as a whole. We note these studies by naming the city in parentheses after the name of the country.

Results

The studies that provided an average estimate of male AR CAG repeats are cited in Table 1 along with the following items of information: the country sampled, the average AR CAG repeat reported, the specific type of average, the size of the sample, and any relevant qualifying comments, particularly regarding the sample reported.

Table 1 presents findings from a total of 189 studies from 78 different countries. The total number of males sampled was 23,540. Countries with the largest number of studies were the United States (14), Sweden (13), China (10), Germany (8), India (6), and Iran (5).

Table 1. *Individual studies of average AR CAG repeats and the countries from which they derived their samples.*

Country	Avg. CAG repeats	Type of average	N	Source Reference	Comments (C = control group)
Algeria	21.02	mean	296	Esteban et al. 2004	
Angola	20.89	2 modes	87	Vokwana 2008, Table 3.1	
Austria	22.00	mean	190	Gsur et al. 2002	C prostate cancer
Australia	20.50	mean	32	Dowsing et al. 1999	C infertility
Australia	21.00	mean	5	Cram et al. 2000	
Australia	25.50	mean	50	Jin et al. 2000:93	
Australia	21.00	median	107	Ellis et al. 2007:453	C baldness
Australia	21.90	mean	456	MacLean et al. 2004:Table 2	Controls
Australia	22.20	mean	38	Owens et al. 2019:Table 2	C schizophrenia
Barbados	19.60	mean	2,261	Ackerman et al. 2012	
Belgium	21.00	mean	181	Legius et al. 1999	C infertility
Belgium	21.80	mean	354	Huhtaniemi et al. 2009:Table 2	
Brazil (Sao Paulo)	20.65	mean	200	Ribeiro et al. 2002	
Brazil	22.07	mean	279	Dos Santos et al. 2003	C prostate cancer
Brazil	20.20	mean	72	De Abreu et al. 2007	
Brazil	21.51	mean	100	Neto, Koff et al. 2008:76	
Bulgaria	22.00	2 modes	261	Kachakova et al. 2016:Fig. 2	
Canada	21.00	mean	163	Hurd et al. 2011:Fig. 8	College students
Cent. Afr. Rep.	20.40	mean	36	O’Brien et al. 2004	
Cent. Afr. Rep.	19.29	2 modes	59	Vokwana 2008:Table 3.1	

Country	Avg. CAG repeats	Type of average	N	Source Reference	Comments (C = control group)
Chile	22.70	mean	79	Parada-Bustamante et al. 2010	C infertility
China (Shanghai)	23.00	median	300	Hsing, Gao et al. 2000	
China	22.50	mean	50	Jin, Beilin et al. 2000:93	
China (Hong Kong)	23.00	mean	45	Tse et al. 2003:229	C infertility
China	22.10	mean	31	Li et al. 2005	C infertility
China	22.00	mode	101	Wang et al. 2007:2025	
China (Shanghai)	23.10	mean	726	Meyer et al. 2010	C cancer
China	22.50	mean	96	Han et al. 2013	
China	22.62	mean	163	Mao et al. 2014:Table 1	
China	22.00	median	302	Shi et al. 2017	
China	23.00	mean	953	Yang et al. 2017	
China	24.70	mean	111	Hong et al. 2018	
Congo, Dem. Rep.	18.00	mean	117	Vokwana et al. 2008:Table 3.1	
Croatia	21.90	mean	209	Skrgatic et al. 2012	
Denmark	21.50	mean	87	Rajpert-De Meyts et al. 2002	
Ecuador	22.00	mean	148	Robles Ruiz et al. 2012	
Egypt	18.18	mean	52	Badran et al. 2009	C infertility
Egypt	19.60	mean	20	Mosaad et al. 2012	
England	18.50	median	32	Kremer et al. 1994: Table 2	
England	22.00	mean	390	Edwards et al. 1999	
England	23.00	median	850	Lim et al. 2000:Fig. 1	C under-masculinization
England	21.50	mean	111	Oxynos et al., 2003	
England	21.00	mode	749	Forrest et al. 2005:Fig. 1	C prostate cancer
Estonia	21.20	mean	212	Saare et al. 2008	
Estonia (Tartu)	22.30	mean	294	Huhtaniemi et al. 2009:Table 2	
Estonia	21.00	median	974	Grigorova et al. 2017:Fig. 1A	
Finland	22.41	mean	149	Lund et al. 2003:Table 1	C infertility
France	22.18	mean	156	Latil et al. 2001:1132	C prostate cancer
France	22.20	mean	50	Wallerand et al. 2001	C infertility
France	22.80	mean	13	Dakouane-Giudicelli et al. 2006	
France	22.10	mean	814	Nicolaiew et al. 2009:103	C prostate cancer
Germany	18.00	median	8	Kremer et al. 1994: Table 2	
Germany	21.00	mode	105	Correa-Cerro et al. 1999:329	C prostate cancer
Germany	24.00	mean	53	Hiort et al. 1999	
Germany	20.80	mean	22	Dadze et al. 2000	C infertility

Country	Avg. CAG repeats	Type of average	N	Source Reference	Comments (C = control group)
Germany	23.00	mean	53	Hiort et al. 2000	
Germany	19.90	mean	131	von Eckardstein et al. 2001	C infertility
Germany (Munich)	21.00	mode	111	Sasaki et al. 2003:1246	
Germany	22.20	mean	330	Arning et al. 2015	
Greece	21.00	mean	64	Kukuvitis et al. 2002	C infertility
Greece	21.33	mean	66	Esteban et al. 2006:Table 1	
Greece	22.49	mean	170	Goutou et al. 2009: Table 1	
Greece	22.05	mean	114	Lazaros et al. 2008	
Greenland	23.00	mean	197	Giwereman et al. 2006	
Greenland	22.90	mean	213	Brokken et al. 2013:Table 3	
Hungary (Szeged)	22.20	mean	383	Huhtaniemi et al. 2009:Table 2	
Iceland	20.00	median	6	Kremer et al. 1994: Table 2	
Iceland	23.10	mean	77	Lavery et al. 2005	C infertility
India	19.00	mode	109	Saleem et al. 2000: Fig. 1a	Controls
India	22.40	mean	201	Thangaraj et al. 2002	C infertility
India	21.50	mean	59	Dhillon & Husain 2003	
India	22.98	mean	133	Mishra et al. 2005: Table 1	C prostate cancer
India	20.90	mean	119	Vijayalakshmi et al. 2006:Table 1	
Indonesia	22.68	mean	25	Soeharso et al. 2004	
Iran	21.80	mean	190	Radpour et al. 2007:Table 3	C hypospadia
Iran	22.80	mean	100	Ashtiani et al. 2011	C prostate cancer
Iran	19.96	mean	72	Khatami et al. 2015	C infertility
Iran	21.10	mean	203	Zare-Karizi et al. 2016	
Iran	17.53	mean	150	Mobasseri, et al. 2018	
Ireland	23.07	mean	77	Lavery et al. 2005	
Israel	23.00	mean	20	Panz et al. 2001	C prostate cancer
Israel	16.60	mean	21	Madgar et al. 2002	C infertility
Israel	21.67	mean	114	Milatiner et al. 2004:Table 1	C infertility
Italy	19.00	median	29	Kremer et al. 1994: Table 2	
Italy	21.60	mean	115	Ferlin et al. 2004:Table 1	C infertility
Italy	21.50	median	91	Canale et al. 2005:Fig 1	
Italy	20.00	mode	61	Giagulli et al. 2014:Figure 1	

Country	Avg. CAG repeats	Type of average	N	Source Reference	Comments (C = control group)
Italy (Florence)	22.30	mean	407	Huhtaniemi et al. 2009:Table 2	
Ivory Coast	19.13	mean	89	Esteban et al. 2006:Table 1	
Japan	21.40	mean	36	Komori et al. 1999	
Japan	23.90	mean	48	Yoshida et al. 1999	
Japan	23.70	mean	51	Sasagawa et al. 2001	C infertility
Japan	22.60	mean	109	Li et al. 2003:Table 3	
Japan (Sapporo)	22.00	mode	111	Sasaki et al. 2003:1246	
Jordan	19.00	median	145	Batiha et al. 2018	
Jordan	19.35	mean	169	Al Zoubi et al. 2020	
Kazakhstan	22.59	mean	40	Borinskaya et al. 2004	
Kenya	22.60	mean	156	Campbell et al. 2009	
Kenya	21.40	mean	12	O'Brien et al. 2009	
Latvia	22.00	mean	1,557	Erenpreiss et al. 2008:479	Military recruits
Lithuania	23.00	mode	974	Grigorovna et al. 2017	
Macedonia	22.28	mean	152	Madjunkova et al. 2012:33	
Malaysia	22.00	mean	72	Tan et al. 2019:246	C infertility
Martinique	20.00	mean	253	Veronique-Baudin et al. 2006	
Mexico	20.88	mean	40	Martinez-Gacia et al. 2008:657	C infertility
Mexico	19.50	mean	326	Gomez et al. 2016:Fig. 1	C prostate cancer
Mongolia	23.00	median	196	Huang et al. 2015	
Morocco	21.02	mean	296	Esteban et al. 2006:Table 1	
Namibia	18.52	2 modes	109	Vokwana 2008:Table 3.1	
Netherlands	21.70	mean	70	Van Golde et al. 2002	C infertility
New Zealand	20.99	mean	105	Erasmuson 2003	
Nigeria	16.70	mean	83	Kittles et al. 2001: Table 1	
Nigeria	19.50	mean	38	Akinloye et al. 2009:Table 1	
Norway	19.50	median	10	Kremer et al. 1994: Table 2	
Norway	21.62	mean	172	Skjaerpe et al. 2010:Table 1	
Philippines	21.08	mean	674	Gettler et al. 2017	
Philippines	21.10	mean	722	Ryan et al. 2017:Table 1	
Poland (Lodz)	22.40	mean	393	Huhtaniemi et al. 2009:Table 2	
Poland (Warsaw)	22.00	mean	187	Brokken et al. 2013:Table 3	

Country	Avg. CAG repeats	Type of average	N	Source Reference	Comments (C = control group)
Poland (Lublin, Poznan)	22.90	mean	180	Kamieniczna et al. 2015:Fig. 1A	
Portugal	21.50	mean	31	Silva-Ramos et al. 2006:332	
Romania	23.16	mean	130	Radian et al. 2010	
Russia	18.00	median	8	Kremer et al. 1994: Table 2	
Russia	21.00	median	417	Melikyan et al. 2020	Controls
Saudi Arabia	21.00	mean	56	Tayeb et al. 2004	C prostate cancer
Scotland	19.00	median	20	Kremer et al. 1994: Table 2	
Senegal	17.90	mean	24	O'Brien et al. 2004	
Sri Lanka	22.50	mean	110	Malavige et al. 2017	
Sierra Leone	17.30	mean	230	Kittles et al. 2001: Table 1	
Singapore	23.00	mode	72	Tut et al. 1997:Table 1	C infertility
Singapore	23.12	mean	87	Mifsud et al. 2001a	
Singapore	22.98	mean	91	Mifsud et al. 2001b	
Singapore	21.90	mean	46	Das et al. 2008	C prostate cancer
Slovakia	22.04	mean	147	Durdiakova et al. 2013	
Slovenia	19.35	mean	137	Peterlin et al. 2007	
South Africa	22.00	mean	40	Panz et al. 2001 (20 white, 20 black)	C prostate cancer
South Korea	21.60	mean	135	Jeong et al. 2004	
South Korea	22.50	mean	600	Du Geon Moon et al. 2017	
South Korea	22.30	mean	337	Kim, Bae et al. 2018	
Spain	22.40	mean	96	Mengual et al. 2003	
Spain	22.07	mean	217	Esteban et al. 2006:Table 1	
Spain	22.10	mean	108	Aluja, Garcia et al. 2011:234	C personality
Spain	22.11	mean	105	Aluja, Garcia et al. 2015:92	
Spain (Madrid)	21.00	median	319	Gonzales et al. 2017	
Swaziland	17.00	median	91	Vokwana et al. 2009	
Sweden	17.00	median	103	Kremer et al. 1994: Table 2	
Sweden	23.20	mean	294	Giwercman et al. 1998	
Sweden	21.70	mean	186	Bratt et al. 1999:673	C prostate cancer
Sweden	21.00	mode	105	Jonsson et al. 2001:Table 1	
Sweden	22.50	mean	254	Li, Gronberg et al. 2003:Table 3	
Sweden	21.90	mean	210	Aschim et al. 2004	C infertility
Sweden	21.90	mean	223	Ruhayel et al. 2004	
Sweden	22.50	mean	125	Andersson et al. 2006	C prostate cancer

Country	Avg. CAG repeats	Type of average	N	Source Reference	Comments (C = control group)
Sweden	22.10	mean	302	Giwereman et al. 2006	
Sweden	22.00	median	266	Tiido et al. 2007	Fishermen
Sweden	22.00	mean	308	Huhtaniemi et al. 2009:Table 2	
Sweden	21.00	median	172	Skjaerpe et al. 2009:Figure 1	
Sweden	22.00	mode	146	Westberg et al. 2009:Table 1A	
Switzerland	21.00	median	139	Hersberger et al. 2005	
Taiwan	23.00	median	349	Yu et al. 2000:2025	
Taiwan	21.0	mean	47	Pan et al. 2202	C infertility
Taiwan	22.90	mean	104	Huang et al. 2003	
Taiwan	23.50	mean	108	Cheng et al. 2006:550	C criminal violence
Taiwan	22.90	mean	478	Liu et al. 2015:Table 1	
Tanzania	21.00	median	122	Butovskaya et al. 2012	
Thailand	23.10	mean	1,494	Ackerman et al. 2012	
Tunisia	21.13	mean	98	Hadjkacem et al. 2004	
Turkey	22.41	mean	32	Tufan et al. 2005	
Turkey	22.59	mean	149	Esteban et al. 2006:Table 1	
Turkey	21.63	mean	63	Tug et al. 2018:432	C micropenis
Uganda	21.00	mode	120	Vokwana et al. 2009	
Ukraine (Kharkiv)	22.40	mean	157	Brokken et al. 2013:Table 3	
USA	20.30	mean	101	Cortzee & Ross 1994	
USA	22.00	median	22	Sawaya & Shalita 1998:9	
USA	21.59	mean	150	Platz et al. 2000:Table 3	
USA	20.72	mean	55	Mifsud et al. 2001a	
USA	22.00	mean	45	Patrizio et al. 2001	C infertility
USA	21.00	mean	55	Casella et al. 2003	
USA (Los Angeles)	22.00	median	2,160	Freedman et al. 2005	
USA	21.00	mode	1,968	Slattery et al. 2005	C colorectal cancer
USA	22.00	median	294	Walsh et al. 2005	
USA	19.30	mean	13	Katagiri et al. 2006	
USA	21.90	mean	1,353	Price et al. 2010	
USA	22.10	mean	583	Travison et al. 2010:Table 2	
USA (Atlanta)	17.69	mean	36	Mascaro et al. 2014:Table 1	
USA	22.00	mean	195	Figg et al. 2014:Table 1	
Zambia	17.00	mode	55	Vokwana 2008: Table 3.19	

After compiling the findings appearing in Table 1, the results were condensed down to a single average number of AR CAG repeats for each country. The results of this condensation are presented in Table 2. Of course, in the case of countries for which just one study could be located, a country's average number of repeats remained unchanged. For countries with two or more studies, each average AR CAG repeat shown in Table 1 was weighted according to the study's sample size. Then the weighted averages were added together and divided by each country's number of studies to obtain an overall average for each country.

Based on a total sample of 57,826 males occupying 78 countries, the overall average number of AR CAG repeats was found to be 21.40. National averages ranged from 17.00 to 23.16. Five countries had averages in the 17.00s; they were Swaziland (17.00), Zambia (17.00), Sierra Leone (17.30), Nigeria (17.58), and Senegal (17.90). Five countries had averages of 23.00 or higher; they were Lithuania (23.00), Mongolia (23.00), Ireland (23.07), Thailand (23.10), and Romania (23.16).

Table 2. *Overall average androgen receptor CAG repeats by country.*

Country	N studies	N males	CAG repeats
Algeria	1	296	21.02
Angola	1	87	20.89
Austria	1	190	22.00
Australia	6	688	21.97
Barbados	1	2,261	19.60
Belgium	2	535	21.53
Brazil	4	651	21.34
Bulgaria	1	261	22.00
Canada	2	163	21.88
Central Afr. Rep.	2	95	19.71
Chile	1	79	22.70
China	11	2,878	22.75
Congo, Dem. Rep.	1	117	18.00
Croatia	1	209	21.90
Denmark	1	87	21.50
Ecuador	1	148	22.00
Egypt	2	72	18.57
England	5	2,132	21.97
Estonia	3	1,480	21.29
France	4	1,033	22.13
Finland	1	149	22.41
Germany	8	858	21.60
Greece	4	414	21.95
Greenland	2	410	22.95

Country	N studies	N males	CAG repeats
Hungary	1	383	22.20
Iceland	2	83	22.88
India	5	621	20.63
Indonesia	1	25	22.68
Iran	5	715	20.66
Ireland	1	77	23.07
Israel	3	232	21.15
Italy	5	703	21.74
Ivory Coast	1	89	19.13
Japan	5	355	22.62
Jordan	2	314	19.19
Kazakhstan	1	40	22.59
Kenya	2	168	22.51
Latvia	1	1,557	22.00
Lithuania	1	974	23.00
Macedonia	1	152	22.28
Malaysia	1	72	22.00
Martinique	1	253	20.00
Mexico	2	366	19.65
Mongolia	1	196	23.00
Morocco	1	296	21.02
Namibia	1	109	18.52
Netherlands	1	70	21.70
New Zealand	1	105	20.99
Nigeria	2	121	17.58
Norway	2	182	21.50
Philippines	2	1,396	21.09
Poland	3	760	22.42
Portugal	1	31	21.50
Romania	1	130	23.16
Russia	2	425	20.94
Saudi Arabia	1	56	21.00
Scotland	1	20	19.00
Senegal	1	24	17.90
Sri Lanka	1	110	22.50
Sierra Leone	1	230	17.30
Singapore	4	296	22.86
Slovakia	1	147	22.04
Slovenia	1	137	19.35

Country	N studies	N males	CAG repeats
South Africa	1	40	20.00
South Korea	3	1,072	22.32
Spain	5	845	21.66
Swaziland	1	91	17.00
Sweden	13	2,694	21.88
Switzerland	1	139	21.00
Taiwan	5	1,086	22.91
Tanzania	1	122	21.00
Thailand	1	1,494	23.10
Tunisia	1	98	21.13
Turkey	3	244	22.32
Uganda	1	120	21.00
Ukraine	1	157	22.40
USA	14	7,030	21.63
Zambia	1	55	17.00

Conclusions

This study was undertaken to obtain estimates of national averages in male AR CAG repeats. The overall average repeat numbers for all 78 countries for which data were obtained from a total of 57,826 research participants was 21.40. Country-by-country average repeats ranged from 17.00 for Swaziland and Zambia to 23.16 for Romania.

We wish to underscore that few if any of the national samples can be considered representative of an entire country, although the averages are likely to be close estimates. This is partly because many of the sample sizes were small (often below 200 per study), and partly because most of the samples were drawn from regions within countries. Therefore, as research on AR CAG repeats continues to be published, the findings presented here should be updated.

In rough geographic terms, Table 2 indicates that males from Sub-Saharan African countries have the fewest average numbers of repeats, all in the 17-20 range, with the exception of Kenya's 22.51. AR CAG repeats for males in the northern African and Middle Eastern countries were generally in the 19-21 range. The countries where our analysis found the highest AR CAG repeats were in the Eurasian continent; these countries were generally in the 22-23 range (Scotland's average of 19.00, based on a sample of 20 individuals, being an exception). Finally, most samples drawn from both North and South American countries were in the 21-22 range.

Researchers interested in conducting ecological analyses of how male AR CAG repeats vary by country may find Table 2 useful. Both health-related and behavior-related traits influenced by AR CAG repeats are likely to vary country-to-country in accordance with the average AR CAG repeats shown in Table 2.

Finally, it is worth stating that, even though we limited our sampling to males, the national variations shown in Table 2 are equally valid for females. This is because males have just one androgen receptor gene that they inherit from their mothers. Presumably, which of the two X chromosomes a mother contributes to her male offspring is randomly determined.

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